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Rails.

Specifications and use.

Results of tests and future developments (1) (2),

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Figs. 1 to 60, pp. 1569 to 1605.

The rail question and manufacturing methods.

To judge by the technical literature that has appeared on the subject of « Rails » during recent years, it must be agreed that there really is a rail question, as most of the railways are actively occupied in research work with the view of improving the steel in order to correct the defects in quality shown by rails in service.

If an attempt were made *a priori* to set up a scale of rail quality based on the ordinary methods of manufacture, it would be very difficult to show the superiority of any one process, and we should be led to state that the enquiries directed in different directions, but always having the quality in view, have been made both by those who use open hearth or acid Bessemer steel, and by those who, for certain reasons, prefer basic Bessemer steel rails.

It must be admitted, however, that the 38-kgr. and 52-kgr. (76.6 and 104.8 lb. per yard) acid Bessemer steel rails supplied to us up to 1893, the year in which the basic Bessemer (Thomas) process came into general use in Belgium, wore better than our present rails. The fact is incontestable, since we still possess in our main lines some of these rails which have not yet reached their maximum limit of wear. At that time, the works were satisfied with a moderate output and were able to use raw materials of the very best grade (ore, coke, etc.), but there can be no doubt that it would be impossible to-day to obtain the high ton-

(1) Lecture given on 11 December 1929 at the Railway Headquarters, Brussels, before the Professional Union of Technical Inspectors and Heads of Sections.

(2) Translated from the French.

nages of rails required, having the same qualities.

Without in any way wishing to lessen the value of the acid Bessemer process for the manufacture of rails, it is necessary, however, not to exaggerate when forming an opinion as to the value of the rails; there is obviously a tendency to judge the Bessemer rails from those remaining in service, that is to say, from the best rails, the others, the bad rails, having been eliminated as a matter of course as time has passed.

The same selection will also make itself felt in the case of the basic Bessemer (Thomas) rails, and it may be stated that we still possess in our main lines, 40.65-kgr. (82 lb. per yard) basic Bessemer rails dating from 1903-1904 and even from 1898, which have thus given 25 to 30 years service without reaching the maximum limit of wear.

In Belgium, as regards the ordinary quality of rails, we have at present only to consider the basic Bessemer process. The same applies also to France and Germany, as regards the greater part of the tonnage manufactured. We shall consider, therefore, more particularly basic Bessemer rails.

In a general way, we are bound to recognize that the amazing growth of the means of production, which took place within the last quarter of a century, was not followed by a corresponding improvement in quality.

Happily railway companies are to-day again turning their minds to better quality, especially as regards rails.

Traffic and unit loadings.

During the same period, there was a rapid growth in railways — a growth too well known to necessitate review here.

Progress has been unceasing and surprising in passengers and tonnage carried, in axle loads of locomotives, carriages and wagons, and in speed.

For the purpose of fixing our ideas, a few figures will be given to emphasise the importance of this growth.

From 1913 to 1928, the number of tonnes-goods-kilometres carried on our railways increased from 5 290 millions to nearly 7 808 millions, while the number of trains decreased from 787 000 to 664 000, and the number of goods-trains-kilometres fell from 36 to 30 millions. This result is due to the increase in the useful load which has risen from 173 to 297 metric tons per train.

In brief, as regards goods alone, the Belgian railways, in 1928, carried 47 % tonne-kilometres more than in 1913, with 16 % fewer train-kilometres.

The same comparison cannot be given for the tonnages represented by passenger trains, because no statistics of this kind were kept in 1913, but some idea of the traffic is given by table I below.

TABLE I.

Year.	Passenger-km. (passenger miles), in millions.	Passenger-train-km. (passenger train-miles), in millions.	Passengers per train-km. (per train-mile).
1913	4 878 (3 031)	46.6 (28.95)	105 (169)
1927	5 780 (3 592)	38 1 (23.7)	152 (245)
1928	6 270 (3 896)	39 9 (24.8)	157 (253)

These data show that the number of passengers per train has increased by about 50 % since 1913.

About 25 years ago, the greater majority of the locomotives only had axles carrying less than 15 t. (14.7 English tons). At the present time, most locomotives have axles carrying more than 18 t. (17.7 Engl. tons) and up to 22 t. and

23 t. (21.6 and 22.6 Engl. tons), has already been projected for future locomotives.

The improvement in the running conditions thus results in an increase in the unit loadings.

It remains to be seen how far one may go in this direction. Everything will depend, from the point of view of the track, on the superstructure, and the qualities of the parts of which it is composed, more particularly of the *rails*, the question of section being assumed to be solved.

The rail and the qualities which it should possess.

In point of fact, although the strengthening of the superstructure of the permanent way has followed more or less the increase in traffic, and although the lay-out of the permanent way and its maintenance have been made systematic and methodically organised, it is none the less true that the rail remains the essential element of safety, the other accessories — ballast, sleepers, etc., — merely serving to support or secure it.

The rough rule « To have good tracks, the chief thing is to have good rails » still retains, therefore, all its importance.

On the other hand, the state of the permanent way has a considerable influence on the satisfactory preservation of the rolling stock; it may also be said that the reverse is true, and that badly designed or badly kept rolling stock may become an important destructive element for the permanent way. We will return to the subject of the rails, however, which for the great railways is a question of primary importance, in the very first place, from the moral obligation of ensuring the *safety* of running of the trains, and in the second place from an *economic* standpoint because of the heavy consumption of costly material.

The difficulty is to define what is a *good* rail.

As far as we are concerned good rails are those which combine the following qualities :

1. Made of *sound metal.*
2. Made of *non-brittle metal.*
3. Made of *metal resisting wear sufficiently.*

We shall see what has been done and what remains to be done to satisfy these three conditions.

I. — Sound metal.

The inspection departments appointed to inspect rails and those responsible for their good upkeep in normal service have to base their opinion on various tests laid down in the specifications.

It is necessary therefore to lay down test conditions which clearly define the features of the metal offered, and which approach or, if need be, exceed the stresses in service.

As regards the first two points: « sound metal » and « non-brittle metal », an opinion may be formed from tests.

As regards the third condition: « resistance to wear » the practical results obtained are taken as a basis, since the testing machines do not satisfy the desired conditions completely.

The new test conditions.

A comparison between the tests specified before 1923 and those since that year is given in table II below.

This table shows that the new technical specification in force since 1923 stipulate a much greater number of impact tests and tensile tests, as well as the provision by the works of complete chemical analyses of all the casts.

TABLE II.

Acceptance tests.

Up to 1923	Since 1923
1. *Preliminary drop tests.* A tup of 1 000 kgr. (2 200 lb.) falling from a height of 4 m. (13 ft. 1 1/2 in.) on a rail placed on flange and resting on supports 1.10 m. (3 ft. 7 5/16 in.) apart.	
On *one* cropped rail top per cast.	On *all the cropped rail tops* of all casts.
2. *Final drop tests.* Tup of 1 000 kg. (2 200 lb). falling from a height of 6 m. (19 ft. 8 1/4 in.) on a rail placed on flange and resting on supports 1.10 m. (3 ft. 7 5/16 in.) apart.	
On *0.5 °/₀ to 1 °/₀* of the rails offered.	On *1 5 °/₀ to 2 °/₀* of the rails offered.
3. *Tensile tests.* *(Centre of head of rail).*	
Test piece 6 mm. (15/64 inch) in diameter, 200 mm. (7 7/8 inches) between reference marks. Requirements: Minimum ultimate stress 70 kgr. (44.4 Engl. tons per sq. inch). Elongation, minimum 10 °/₀. Tests on *0.5 to 1 °/₀* of the rails offered.	Test piece 13.8 mm. (35/64 inch). diameter, 100 mm. (3 15/16 inches) between reference marks. Requirements: Ultimate stress 68 to 78 kgr. (43.2 to 49.5 Engl. tons per sq. inch). Minimum elongation 12 °/₀. Coefficient of quality: Ultimate stress+2 (elongation)>94. Tests on 1.5 to 2 °/₀ of the rails offered.
4. *Resilience (notched bar) tests.* Mesnager test piece 10×10×55 (25/64×25/64×2 11/64 in.) with 2- mm. (5/64 in.) round bottomed notch.	
Nil.	On 1.5 to 2 °/₀ of the rails offered. Each test is made on one test piece taken from the head of rail, one from the web and one from the flange.
5. *Etching tests.* Baumann sulphur print or etching with Heyn's reagent.	
Nil. No cropping specified.	On 1.5 to 2 °/₀ of the rails offered and on 1 °/₀ of the cropped top ends. Minimum amount of cropping imposed: 25 °/₀ off the top of the ingots. Requirement: The rails should be free from pipes and segregation.
6. *Chemical tests.*	
The chemical anaiyses of the casts tested to be supplied by te works.	The complete analyses of all the casts for S, P, Si, C and Mn. to be supplied and checked by the Malines laboratory (samples taken at random).
7. *Brinell hardness tests.* Pressure of 3 000 kgr. (6 660 lb.). Ball 10 mm. (25/64 in.) in diameter. Pressure maintained for 15 seconds	
Nil.	On about 1 °/₀ of the rails offered.
8. *Micrographic tests.*	
Nil.	Carried out for reference purposes.

The new and special tests distinguishing the measures which have been taken are :

1. The use of *macrography* for elimination purposes, and

2. The *resilience* tests on small test pieces for reference purposes with a view to obtaining some idea of the brittleness of the metal.

The present article will consider mainly the new prescriptions.

The large outputs obtained to-day are the result of the development of mechanical and electrical methods in our works.

In order to ensure control of the quality of the rails, more up-to-date methods and more numerous tests are necessary, precisely on account of the manufacturing conditions and also the numerous stresses to which the rails are subjected in service.

Formerly, the *tensile test* — a static test — provided information as to the toughness of the steel and its ductility, the *drop weight test* — a dynamic test — made on short lengths of rails, provided some idea of the brittleness of the steel when new. These tests were considered sufficient, because most of the other conditions, especially the thermal conditions, were complied with as a matter of course by the process of manufacture.

No one will question, for instance, that ingots of one or two tons, of small section ensuring their rapid solidification, rolled slowly into light or medium sections in a large number of passes under slight pressure, constituted a considerable advantage from the point of view of the final product.

Such conditions, however, have not been obtained for a long time. In most of the works, the ingots weigh 4 tons on the average.

After the war, we had the opportunity of examining a large number of broken rails or rails possessing various defects. These rails came from the devastated regions and had been brought into the workshop for straightening and re-cutting.

We had also to study seriously numerous fractures which had occurred on the railways, in tracks which had been considerably worn by the war traffic, and which had never been repaired.

Our observations led to the conclusion that most of the defective rails or of the rails prematurely put out of service had originated from ingot tops.

They had pipes, appearing in the form of longitudinal cracks, and very often considerable segregations or inclusions which had facilitated the growth of fissures across the section and through the fishing holes or had caused local crushing or flaking on the rolling surface.

The excessive number of fractures which occurred in the rails supplied during the first post-war years confirmed this opinion.

The new technical conditions for controlling the quality of rails date from this period.

It was necessary, therefore, in the first place, to endeavour to obain sound metal.

Ingot cropping and segregation.

Our specification stipulates, in the present day conditions of manufacture, that a minimum of 25 % shall be cropped from the ingot top. In many cases, however, this minimum may be insufficient, the depth of the pipe increasing in proportion to the degree of de-oxidation and de-gasification of the metal, but this stipulation does not prejudice the main

clause, namely : that our rails shall be free from piping and segregation.

It is thus not enough for the rails to be free from piping, but they must also be free from segregation, so as to ensure that the metal will be sufficiently homogeneous throughout the section.

The term « free from segregation » calls for a more explicit definition as to its interpretation.

It is obvious that we cannot go so far as to pretend to suppress entirely the segregation resulting from the liquation of the elements composing the steel at the moment of its solidification, the extent of which will be proportional to that of the elements capable of separating out; but we have in mind the supply of steel made from selected pig (low in sulphur), well refined, thoroughly quietened, and afterwards sufficiently cropped at the top and bottom.

It may be considered that these qualities have been obtained when a Baumann sulphur print, or etching for about two minutes with copper ammonium chloride (Heyn's reagent), fails to reveal on the rail section any agglomeration or zone of concentration of impurities contrasting clearly with the background of the print or the etched surface.

Our requirements are restricted to assuming as homogeneous any rail which does not reveal segregation under the above mentioned reagents, while reserving the use of other etching methods for our laboratory researches.

This method of control, called macrography, has its supporters and its adversaries.

The adversaries of macrography as a means of eliminative control for the acceptance of rails state freely that this process, being quantitative only, leaves the way open to an arbitrary application.

This pretext cannot be assumed to be sufficient for discarding the only method enabling valuable information to be gathered regarding the degree of homogeneity of our rails, and enabling those to be rejected which exhibit segregations of impurities capable of facilitating fracture or of causing the rail to be put out of service before its normal wear. Neither tensile tests, structure tests nor impact tests are able to provide the same information.

The manufacture during the last few years has shown that these defects of pipes and segregations can be avoided by *cropping* sufficiently the ingot and by taking the necessary care in the manufacture, a care which should be brought to bear on all the stages of manufacture: composition of the pig, working of the steel, suitable proportions of the de-oxidising additions, heat treatment from the casting of the ingots to the rolling of the rail.

Principal cases of segregation.

The principal cases of segregation or inclusion which may result from manufacture are :

1. *Central segregation*, affecting the web and spreading to the head of the rail and the flange according to the amount cropped, and the inclusion of blow holes or oxide scale, appearing in the form of rolling lines, denote a metal which has been badly quietened, or lack of care in casting (fig. 1).

2. *Reversed segregation*, characterised by a central decarburisation surrounded by a ring of segregation, denoting that rolling was begun before complete solidification of the ingot. Figures 2 to 9 show the results of tests obtained on a rail of this type.

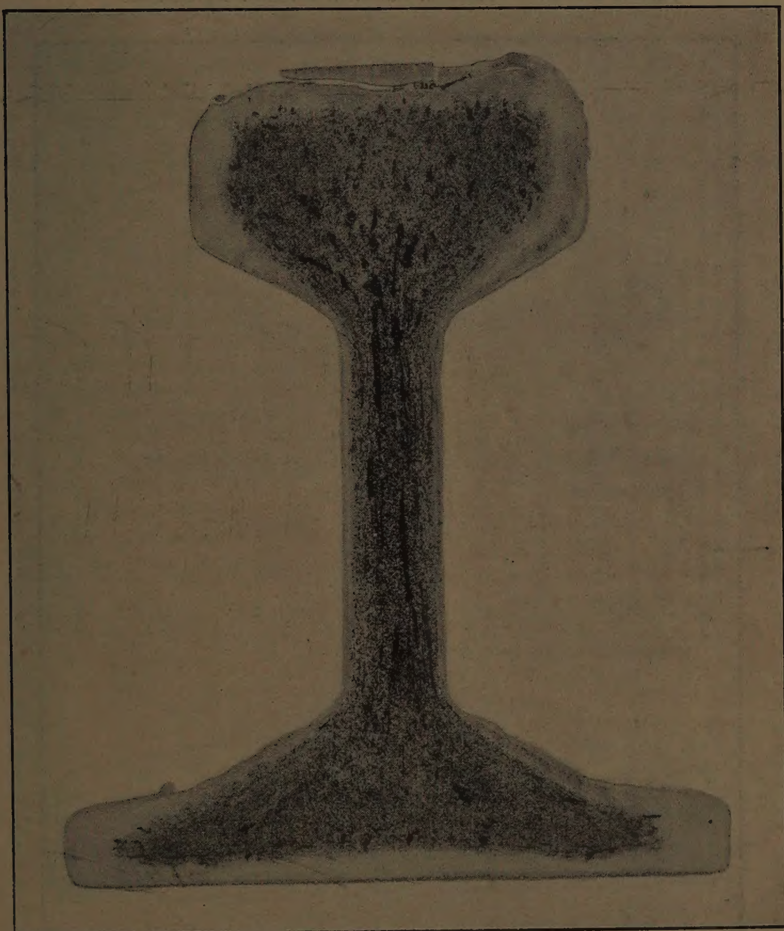


Fig. 1.

3. *Inclusion of soft metal* resulting from the bad practice of protecting the bottoms of ingot moulds against the stream of molten metal by pieces of sheet iron or scrap, which later rise in the molten metal and form inclusions in rails

Figures 2 to 9. — Tests on rail with reversed segregation.

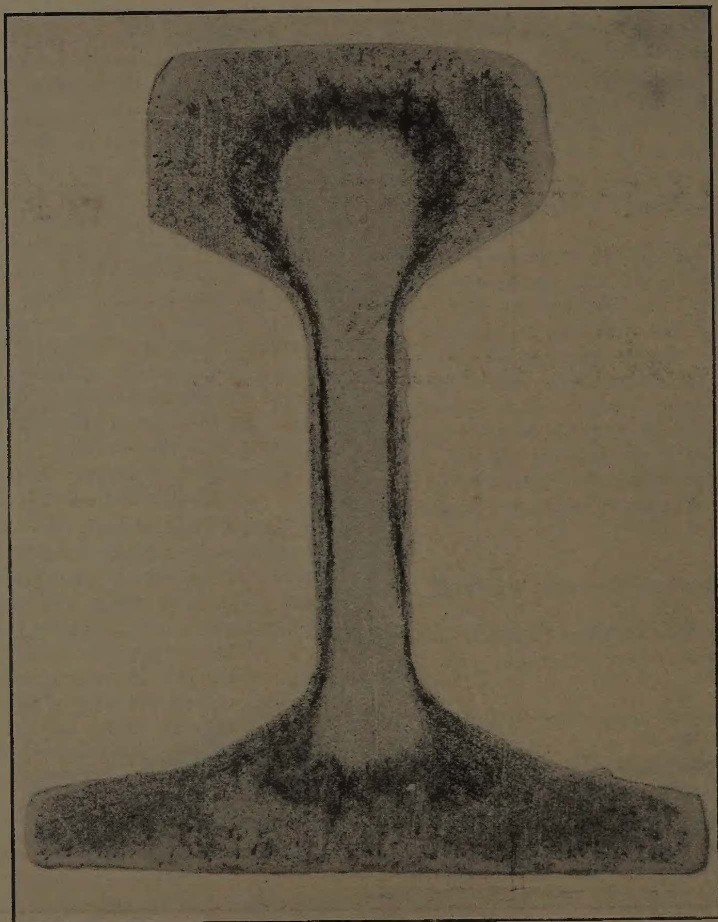
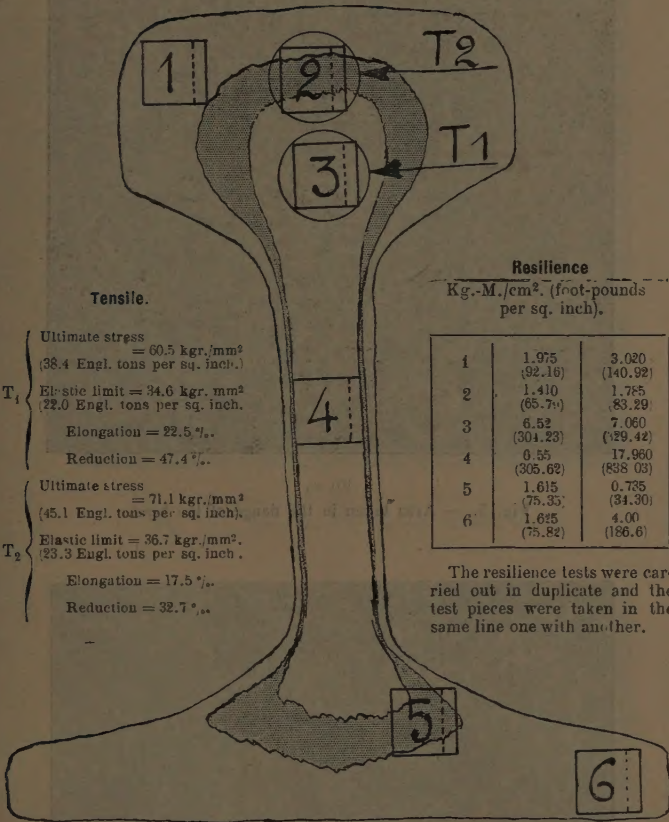


Fig. 2. — Baumann sulphur print.

rolled from the ingot bottom. Figures 10 to 14 relate to a rail contaminated with inclusions of this type.

It is necessary to take all possible measures against these different types of segregation.



Tensile.

T_1:
Ultimate stress = 60.5 kgr./mm² (38.4 Engl. tons per sq. inch.)
Elastic limit = 34.6 kgr. mm² (22.0 Engl. tons per sq. inch.
Elongation = 22.5 %.
Reduction = 47.4 %.

T_2:
Ultimate stress = 71.1 kgr./mm² (45.1 Engl. tons per sq. inch).
Elastic limit = 36.7 kgr./mm². (23.3 Engl. tons per sq. inch .
Elongation = 17.5 %.
Reduction = 32.7 %.

Resilience

Kg.-M./cm². (foot-pounds per sq. inch).

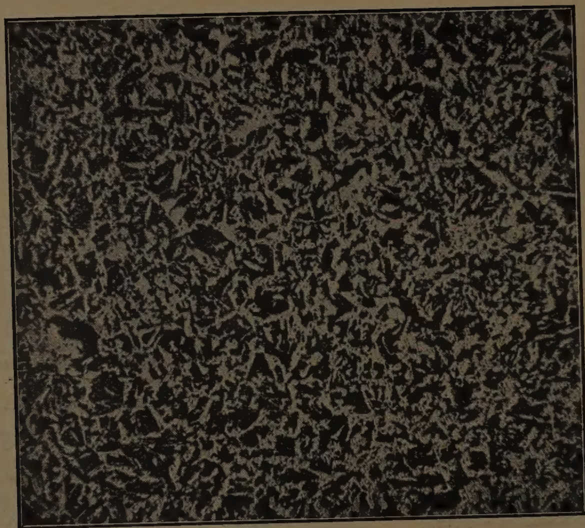
1	1.975 (92.16)	3.020 (140.92)
2	1.410 (65.79)	1.785 (83.29)
3	6.52 (304.23)	7.060 (329.42)
4	6.55 (305.62)	17.960 (838 03)
5	1.615 (75.35)	0.735 (34.30)
6	1.625 (75.82)	4.00 (186.6)

The resilience tests were carried out in duplicate and the test pieces were taken in the same line one with another.

Fig. 3. — Mechanical tests.

The steel makers have repeatedly asked us to state precisely our point of view in illustrative form by providing them with a number of typical macrographs which could be used as a guide both as regards manufacture and for complying with specifications.

In response to this request, our Specification Committee under the chairmanship of Mr. Van Waefelghem, Chief Engineer, drew up the three sets of Baumann sulphur prints shown below, each set comprising five types of macrographs — *good*, *acceptable* and *bad* (figs. 15

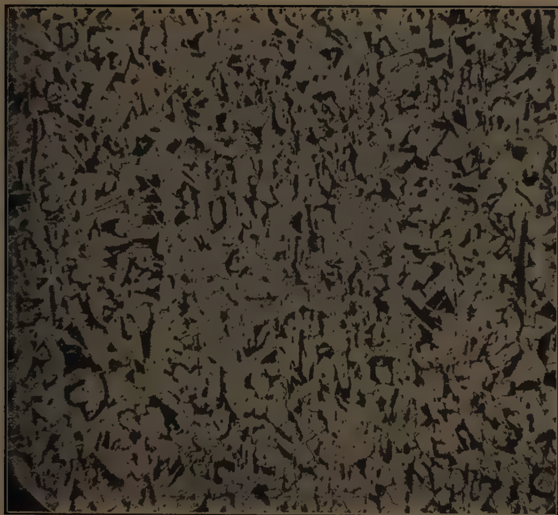


100 ×.

Fig. 5. — Area taken in the flange of the head.

100 ×.

Fig. 6. — Area taken in the segregated zone.



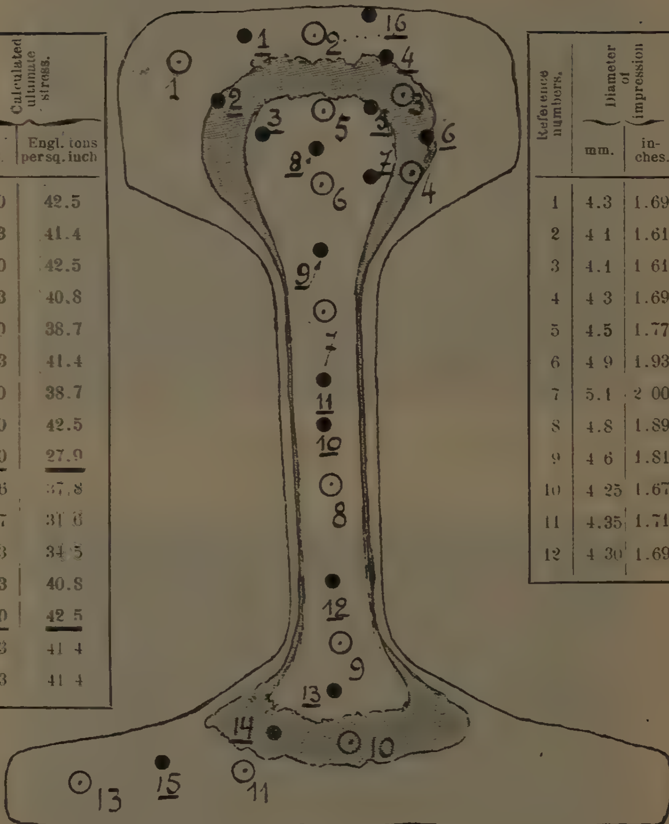
100 ×.
Fig. 7. — Area taken in the decarburised web.

100 ×.
Fig. 8. — Area taken at the edge of the foot.

Figs. 2 to 9 (*continued*).

Position of impressions.

Reference numbers.	Rockwell figure.	Corresponding Brinell figure.	Calculated ultimate stress. kgr/mm².	Calculated ultimate stress. Engl. tons per sq. inch
1	91	192	67.0	42.5
2	90	187	65.3	41.4
3	91	192	67.0	42.5
4	89	179	64.3	40.8
5	87	170	61.0	38.7
6	90	187	65.3	41.4
7	87	170	61.0	38.7
8	91	192	67.0	42.5
9	70	124	44.0	27.9
10	85	166	59.6	37.8
11	76	140	49.7	31.6
12	81	153	54.3	34.5
13	89	179	64.3	40.8
14	91	192	67.0	42.5
15	90	187	65.3	41.4
16	90	187	65.3	41.4



Reference numbers.	Diameter of impression mm.	Diameter of impression inches.	Corresponding Brinell figure.	Calculated ultimate stress. kgr/mm².	Calculated ultimate stress. Engl. tons per sq. inch
1	4.3	1.69	196	68.4	43.2
2	4.1	1.61	217	75.7	48.1
3	4.1	1.61	217	75.7	48.1
4	4.3	1.69	196	68.4	43.4
5	4.5	1.77	179	64.3	40.8
6	4.9	1.93	149	52.9	33.6
7	5.1	2.00	137	48.6	30.9
8	4.8	1.89	156	55.4	35.2
9	4.6	1.81	170	61.0	38.7
10	4.25	1.67	202	70.5	44.8
11	4.35	1.71	192	67.0	42.5
12	4.30	1.69	196	68.4	43.4

Fig. 9. — Hardness tests.

● Tests with the Rockwell machine.
⊙ Tests with the Brinell machine.
Pressure : 3 000 kgr. (6 600 lb.) for 15 seconds. Ball, 10 mm. (25/64 inch) in diameter.

Chemical analyses.

	Segregated zone.	Decarburised zone.	Edge zone.
	%	%	%
S	0.070	0.014	0.048
	0.063	0.012	0.042
P	0.102	0.042	0.075
	0.102	0.043	0.074
Si	0.102	0.102	0.102
	0.102	0.102	0.102
C	0.43	0.26	0.39
	0.44	0.25	0.39
Mn	0.76	0.746	0.787
	0.746	0.76	0.773

Fig. 4.

to 29). We feel sure that the manufacturers will regard the publication of these illustrations merely as a loyal effort on our part with a view to defining more precisely our point of view without any other object.

It may appear superfluous to reproduce good macrographs, but it has been considered desirable to include them in order to show that the best macrographs obtained from rails are not altogether free from segregation in the strict sense of the word; *a fortiori*, those classed as « acceptable » and which for the most part already exhibit pronounced signs of segregation, but without marked agglomeration.

It will be observed that what distinguishes macrograph No. 1 of the set of bad macrographs, from No. 4 of the set of « acceptable » macrographs, is that No. 1 exhibits a filiform segregation. This type of segregation, which forms the immediate extension of the pipe, provided it is not identical with it, possesses, according to the concentration of the impurities, a marked tendency to produce internal fissuration, which will spread more or less rapidly in service under the repeated shocks, and will follow the more or less pronounced crystalline organisation of the surrounding layers, being particularly assisted in this by the fishing holes.

The following experiment has been repeatedly and successfully performed on lengths of rail having a filiform segregation in the web without the appearance of a fissure :

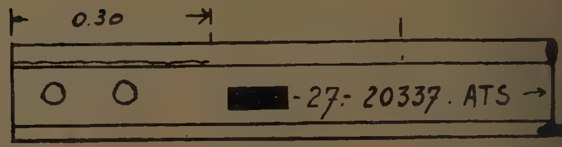
After making a transverse saw-cut in the web down to the line of segregation, a fissure has been produced under the action of repeated blows from a small fitter's hammer weighing about 700 gr. (1.54 lb.), the fissure spreading rapidly along the whole line of segregation and even beyond (see fig. 30).

In short, it is our opinion that segregations constitute a defect of variable degree of seriousness which may not always result in fracture of the rail, but which, nevertheless, ought to be regarded as zones of weakness, the danger from which increases with the concentration of the injurious elements : sulphur, phosphorus and carbon, these elements imparting distinctly different physical properties to the affected zones.

In support of these arguments and to show that our requirements are justified, it is merely necessary to call to mind the shape of our switch points and the shape of the points of built-up crossings. Finally, it should be borne in mind that all rails are pierced by holes in the web,

Figs. 10 to 14. — Inclusion of soft steel, which

Fig. 10. — Macrographic etching showing te zone of soft steel and the split in the rail.



Running direction.

Haine-St-Pierre station (formation).

Ingot bottom rail, 50 kgr. per m. (100.8 lb. per yard), 18 m. (59 ft. 5/8 inches) laid on 27 sleepers.

The rail was split for 0.30 m. (11 13/16 inches) but macrographic etching carried out at 0.60 m. (23 5/8 inches) from the end still showed inclusion of soft steel.

At one metre (3 feet 3 3/8 inches) all trace of soft steel had disappeared.

Date when laid : July, 1927. Cinder ballast.

Date when taken up : December 1927. Level and straight track.

Intense traffic : 200 trains and locomotives per day.

Fig. 11.

at the very place where the elements which may have a harmful effect are often concentrated.

Experience has shown that the formation of fissures and their development under repeated stresses may be considerably promoted by the presence of segregations.

This opinion has recently found fresh support in the noteworthy paper by Messrs. Marqueyrol and Merklen in *Le Génie Civil* for 25 May 1929, entitled « Contribution à l'étude des impuretés dans les rails de chemins de fer », (A contribution to the study of impurities in rails).

This paper, which contains the results of very careful analyses and tests made on segregated rails, leads to the following general conclusions, which have our full support :

1. The more or less extensive areas or zones of impurities to be distinguished in macrographs include high proportions of sulphur and phosphorus. These proportions far exceed the maximum limits usually imposed on manufacturers.

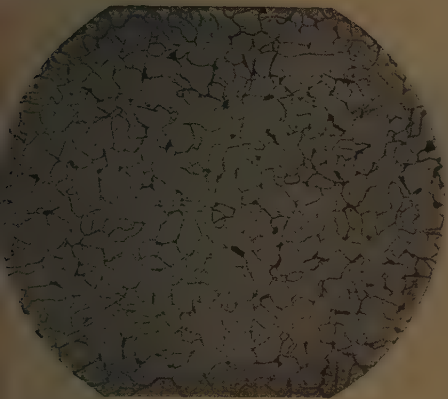
3. The tendency to fissuration is always greater in the zone of impurities than in the sound parts.

3. A very slight fissure originating in a zone of impurities, on passing from one area to another may spread throughout the rail and cause its fracture.

4. Up to the present, it has not been possible to protect the rail joints from the shocks produced by the wheels passing over them.

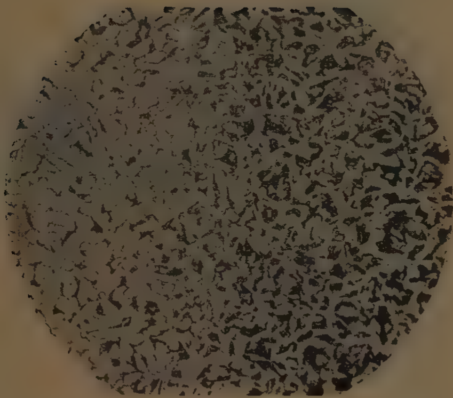
Our experiments on the effect of repeated shocks have shown that regions of high sulphur and phosphorus content have a tendency to fissuration. This at

aused the rail to split longitudinally.



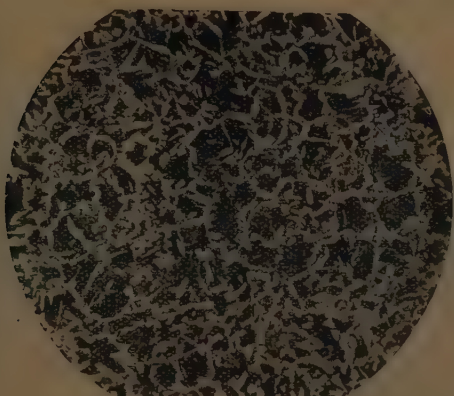
A.

Fig. 12. — Photomicrograph taken in the zone of the soft steel inclusion.



B.

Fig. 13. — Photomicrograph showing the weld of soft steel and hard steel in the transition zone.



C.

Fig. 14. — Photomicrograph showing the normal structure of the rail.

Figs. 15 to 19. — Belgian National Railway Company. — Good macrographs.

(1)

(2)

Figs. 15 to 19 (continued). — Belgian National Railway Company. — Good macrographs

(3)

Fig. 17.

(4)

Fig. 18.

Figs. 15 to 19 (*continued*). — Belgian National Railway Company.
Good macrographs.

Fig. 19.

Figs. 20 to 24. — Belgian National Railway Company. — Acceptable macrographs.

(1)

Fig. 20.

(2)

Fig. 21.

Figs. 20 to 24 (*continued*). — Belgian National Railway Company. — Acceptable macrographs.

(3)

(4)

Figs. 20 to 24 (*continued*). — Belgian National Railway Company. Acceptable macrographs.

(5)

Fig. 24.

Figs. 25 to 29. — Belgian National Railway Company. — Bad macrographs.

(1)

(2)

Fig. 26.

Figs. 25 to 29 (*continued*). — Belgian National Railway Company — Bad macrographs.

(3)

Fig. 27.

(4)

Fig. 28.

Figs. 25 à 29 (*continued*). — Belgian National Railway Company.
Bad macrographs.

(5)

Fig. 29.

once explains the frequent occurrence of fracture in the fishings.

5. The lack of homogeneity, known as segregation, the impurities, blow holes, inclusions of non-metals and foreign metals, etc., are brought to light in a very distinct manner by macrography ; the use of this method is to be recommended, therefore for controlling the quality of supplies.

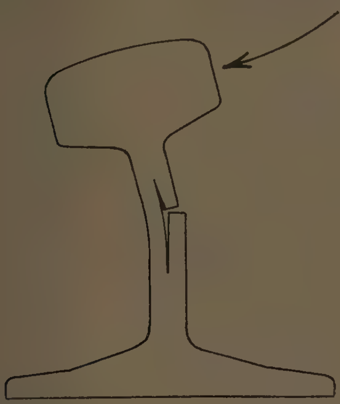


Fig. 30.

On the other hand, we have found that, when an investigation regarding a prematurely broken rail is set on foot, the first test to which the investigator proceeds is a macrographic etching test in order to make sure, before anything else, of the homogeneity of the rail. Why desire to form an opinion of the appearance of the macrographic structure after the fracture has occurred, and not admit of the process as a preventive measure at the time the rails are accepted?

Of course as regards our rails, the results have only been obtained by cropping the ingot tops to an amount which regularly exceeds 30 %.

It is also obvious that it pays to make stipulations of this nature. Ultimately, however, the costs of maintaining the permanent way are reduced owing to the more regular wear, and the less frequent abnormal withdrawal of rails from service. In addition, safety is also benefited.

After all, what would be the use of making considerable efforts to attain greater speeds, to give the passengers more comfort and often more luxury, if it were not possible at the same time to improve the factors of safety, of which the rail constitutes one of the essential elements?

II. — Brittleness.

The causes of brittleness.

A sound metal, however, is not necessarily a metal which is *not brittle*, and we know how much the thermal cycle of manufacture, as well as the mechanical work of rolling, necessary to give the desired shape to the product, may modifiy the structure of metals, that is, of steel, insofar as we are concerned. To a considerable extent the more or less pronounced brittleness of the finished product, for a pre-determined chemical analysis, will depend upon this structure.

From the chemical point of view, the carbon content is the main factor which is capable of affecting the brittleness.

It is impossible to allow high carbon contents for rails without running the risk of a brittleness which would endanger safety. This point will be returned to later, when discussing the wear of rails.

Apart from the quality of the steel, there is the rolling which, starting from the ingot, consists in a series of successive treatments obtained by passing the metal through roughing and finishing grooves, so as ultimately to produce the desired section without re-heating.

This rolling, like forging, is assisted by the high temperatures of the metal, but the result of this is an overheated structure with its characteristic brittleness (figs. 31, 32 and 33).

Although in the case of forging, recourse is had regularly to subsequent reheating, which regenerates the grain, or even to a complete heat treatment, that is to say, hardening followed by tempering, in the case of the rail, on the contrary, rolling, in the ordinary conditions of manufacture is not followed by any treatment capable of regenerating the structure of the metal.

It is therefore necessary to make the rolling conditions such that the best possible crystalline structure is obtained, which will make itself felt in a less pronounced brittleness of the metal.

Resilience tests and the results obtained.

We have therefore been induced to turn our attention to the resilience test, which should provide some indication as to the brittleness of the metal, and that is why, since 1923, we have carried out for reference purposes, resilience tests on small test pieces of the Mesnager type, 10 mm. × 10 mm. × 55 mm. (25/64 × 25/64 × 2 11/64 inches) having a 2-mm. (5/64-inch) round-bottomed notch.

Our object was to be able to determine the capacity for specific work of the various parts of the rail metal, microscopic examination carried out on sections of the resilience test pieces being intended to complete the indications and to be used in searching for possible improvements.

Below is given a frequency diagram for the years 1926, 1927, 1928 and 1929 (fig. 34).

These data were collected on a total of more than 200 000 tons of rails offered for acceptance.

The diagram shows that the manufacture of rails has made incessant progress from the point of view of *non-brittleness*, and it should be borne in mind that, for 1929, more than 80 % of the rails tested gave a resilience of more than 2 Kg.-M. per cm² (93 foot-pounds per sq. inch) and 65 % more than 3 Kg.-M. per cm² (140 foot-pounds per sq. inch).

The improvement has made itself chiefly felt as regards the figures from 3 to 5.

The influence of the rolling temperature on the properties of rails.

It may be of interest to mention that the improvement recorded this year is partly due to a reduction of the final rolling temperature.

In fact, during the rolling programme of 1928, several tests were made, consisting in reducing the temperature in the finishing grooves down to the neighbourhood of 900° C. (1 652° F.).

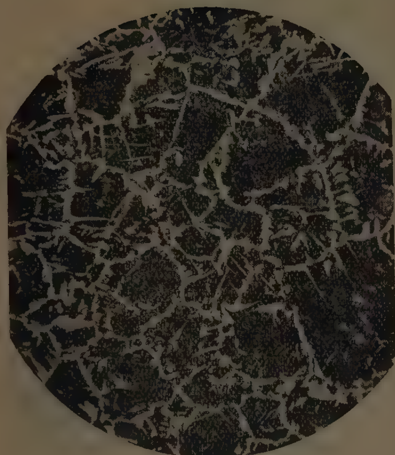
The distribution of the perlitic network was appreciably improved (figs. 35 to 37) and the mechanical characteristics — elastic limit, ultimate stress and resilience — were increased by several units.

For this reason recommendations were made in 1929 to the manufacturers, and the results obtained have confirmed the satisfactory influence of this practice.

Similar experiments have been made and are still being made at some French works, where an endeavour has been made to finish rolling at a temperature as close as possible to the transformation point on cooling. The results which have been communicated to us show a marked improvement, especially from the point of view of « brittleness ».

In *Stahl und Eisen* for 7 February 1929, Mr. Stumper gives the results of his

Figs 31 to 33. — Widmanstätten structures, characteristic of overheatin .



75 X.

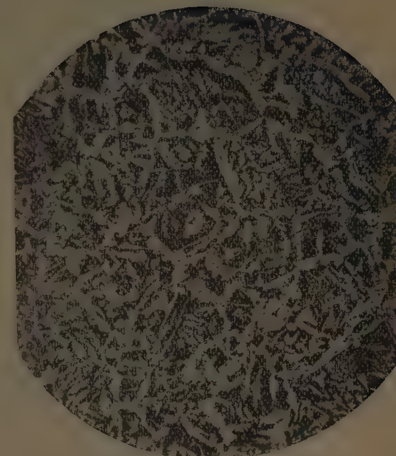
Direction transverse to rolling.

Fig. 31

75 X.

Rolling direction.

Fig. 32.

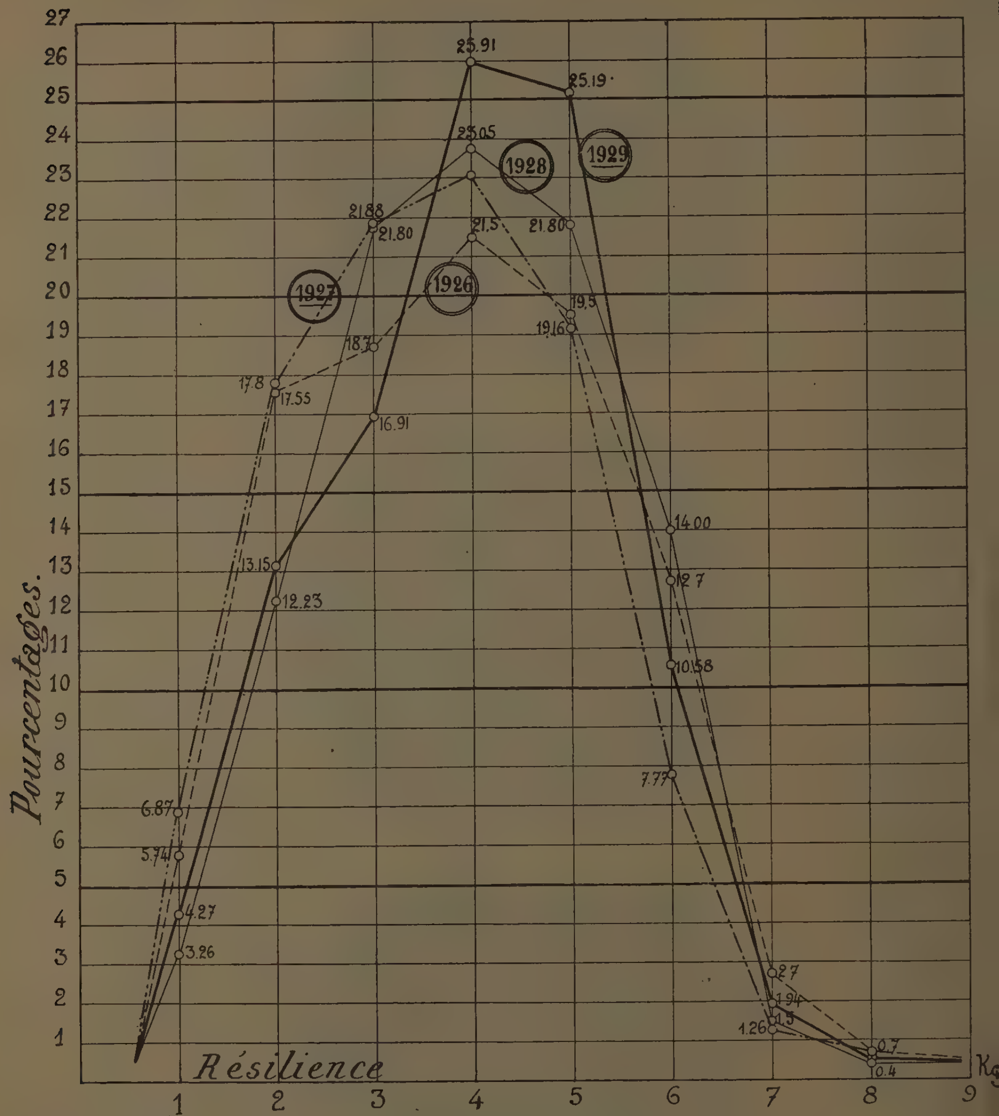


75 X.

Transverse direction.

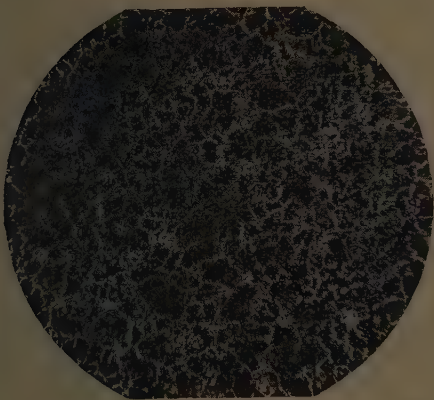
Fig. 33.

Fig. 34. — Results of resilience tests made on rails. (Ordinates = percentages).



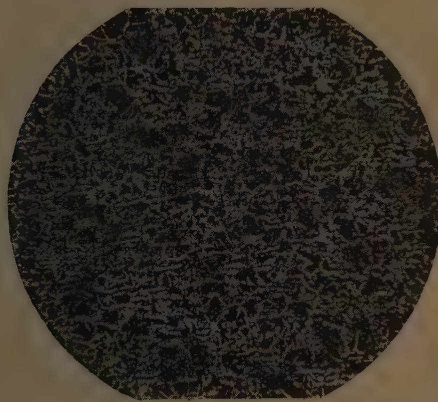
1926	5.74 %	17.55 %	18,7 %	21,5 %	19,5 %	12,7 %	2,7 %	0,7 %	
1927	6.87 %	17.8 %	21,88 %	23,05 %	19.16 %	7.77 %	1,26 %	0,72 %	
1928	3.26 %	12.23 %	21.80 %	23.75 %	21.80 %	14.0 %	1.5 %	0.4 %	
1929	4.27 %	13 15 %	16.91 %	25.91 %	25.19 %	10.58 %	1.94 %	0.55 %	

Figs. 35 to 38. — Variation in the structure according to the final rolling temperature.



75 X.

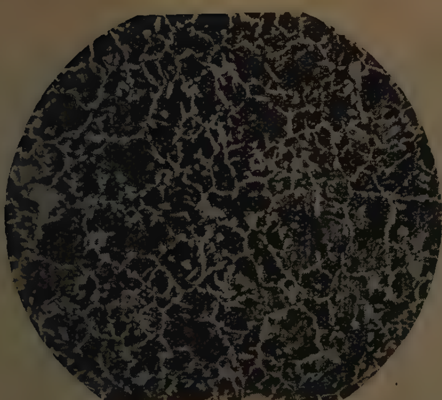
Head.
Fig. 35.



75 X.

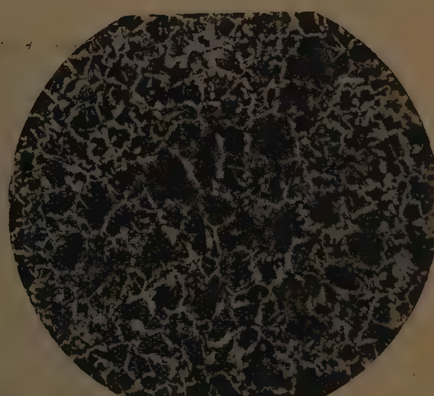
Web.
Fig. 36.

900 to 950° C.
(1 652 to 1 742° F.)



75 X.

Head.
Fig. 37.



75 X.

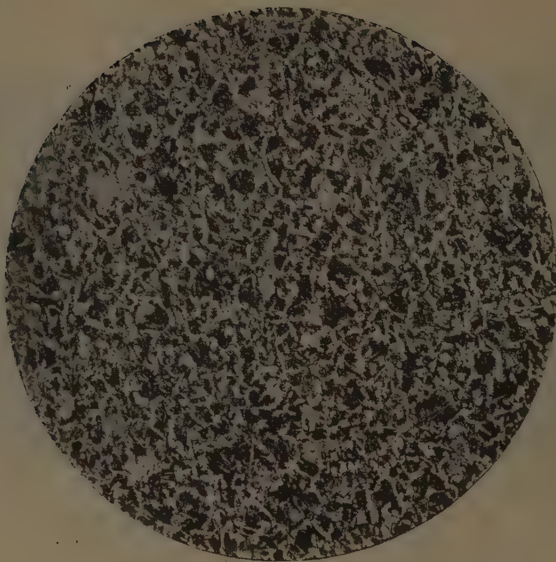
Head.
Fig. 38.

1000 to 1050° C.
(1 832 to 1 922° F.)

work on the influence of the rolling temperature on the properties of rails, these results being based on a series of tests made at the Burbach (Saar) works.

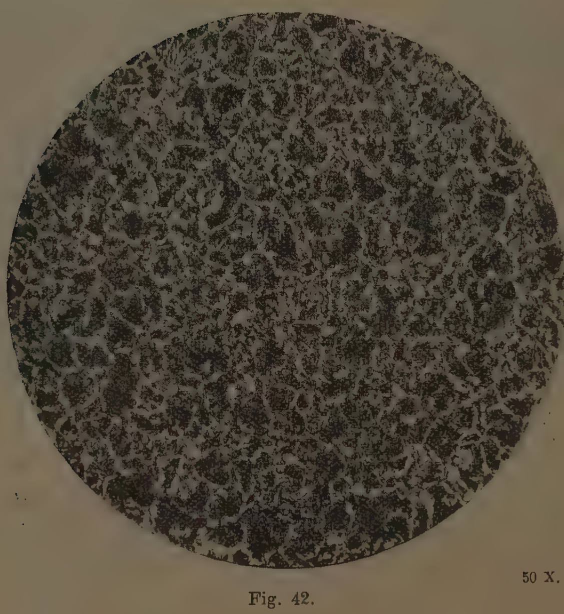
Figs. 39 to 48. — Influence of the final rolling tem

Head.



50 X.

Fig. 39.



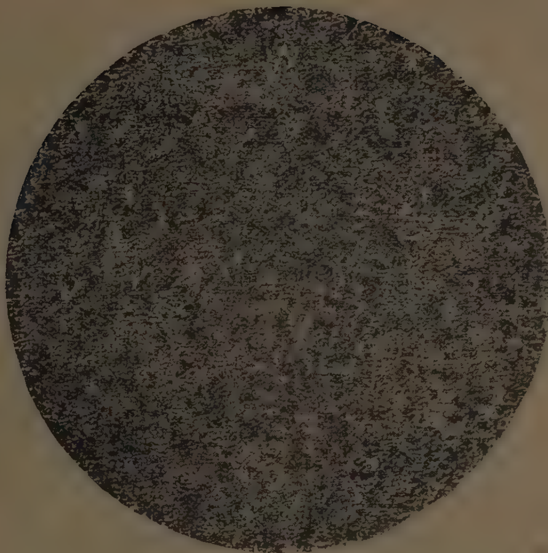
50 X.

Fig. 42.

n the properties of rails, according to Mr. Stumper.

Foot.

50 X.

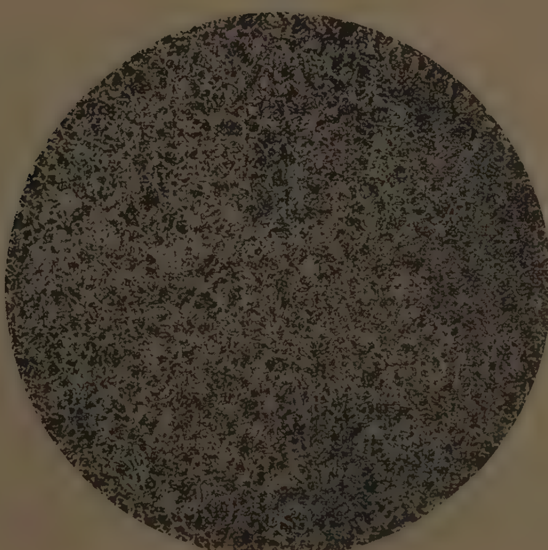


950° C.
(1742° F.).

50 X.

Fig. 41.

50 X.



1050° C.
(1942° F.).

50 X.

Fig. 44.

He finds that the results obtained, relating to a temperature range of 950° to 1 150° C. (1 742 to 2 102° F.) may be summarised as follows :

The elastic limit, the ultimate stress and the elongation decrease when the final rolling temperature increases; whereas the Brinell hardness is only moderately affected, the resilience increases as the temperature decreases.

The improvement in mechanical properties is accompanied by a reduction in the shape of the grain, the size of the grain increasing almost in geometrical progression, when the final temperature increases in arithmetical progression.

Mr. Stumper has been good enough to send us the photomicrographs illustrating his conclusions (see figures 39 to 48).

One of the most interesting results of this method is the elevation of the elastic limit in rail steels. It is, in fact, essential, for the satisfactory resistance to repeated shocks, to endeavour to obtain a high elastic limit.

For many of our rails of an ultimate stress of 70 kgr. (44.4 Engl. tons per sq. inch), the apparent elastic limit often lies between 36 and 38 kgr. (22.8 and 24.1 Engl. tons per sq. in.), which we consider to be insufficient and which should not be less than 40 kgr. per mm² (25.4 Engl. tons per sq. inch). Now this figure of 40 kgr. per mm² has been exceeded regularly when, in the manufacture, the temperature at the end of rolling has been lowered to the neighbourhood of 900° C. (1 652° F.).

In opposition to this, it has been argued that the reduction of the final rolling temperature would cause the roll grooves to wear more rapidly and would result in more frequent breaking of the rolls, while producing a defective section. These objections are justified, and it is evident that it will be necessary to dress the rolls more frequently, and owing to the pressure required, the chance of breaking the appliances will increase.

On the other hand, it is the shape of the section adopted which will serve to fix the limit in lowering the rolling temperature.

As for the surface defects of rails, it is our opinion that they have their origin mainly in rolling flaws or lines which have not properly rewelded and are made more evident by the reduction in the temperature.

Rolling lines are often brought to light and opened out under the impact of the 1 000-kgr. (2 200-lb.) tup with the rail flange in tension. These lines which form fine, longitudinal fissures, may often promote fracture and may originate from surface blisters which have been burst and elongated by the rolling, or from oxide inclusions due to dirty ingot moulds.

The choice of the type of test piece and the shape of the notch.

Difficulties arose at the beginning in procuring in sufficiently large numbers well-gauged resilience test-pieces, any lack of finish in which might have had an adverse effect on the results. That is why the figures from 1926 only have been given, since most of the works have only been equipped gradually with machines for finishing the test pieces and milling the notches.

It has been asked if the small Mesnager test piece is really the one which should be adopted for rail tests. It is accused more particularly of being too local and of not providing indications over the entire rail section. It is also criticised for having a round-bottomed notch, whe-

reas the cracks which are produced in rails in service are always sharp.

In reply to this, it may be stated that, when the brittleness test was adopted, we selected the test weight and the type of test piece which, in the civil and military departments, best answered the requirements.

The shape to be given to the notch has been the subject of considerable discussion in various countries. Quite recently, as the result of some work carried out in Germany [1] on the different existing types of test pieces, two test pieces were retained, one being the Mesnager test piece, as being capable of providing the best indication of brittleness.

Considering that for each test, a test piece is taken from the upper part of the rail head, in the middle of the web and in the flange, it may be assumed that the important parts of the rail are tested.

The usefulness of small test pieces also makes itself felt when it is a question of a rail from an ingot that has been rolled too hot, that is to say, the thermal evolution of which has been too abrupt and abnormal. The resilience figure in such a case is always higher in the web, owing to the resulting decarburisation (figs. 49 to 51).

It must be repeated that it is a matter of considering the averages only of the figures obtained, and their regularity as a whole.

We believe that resilience tests should still be made in the present conditions so as to be in a position to compare the results and follow the progress which has been made.

From now on, however, it is already apparent that, when it becomes a question of finally selecting the shape of the test bar and its notch for indicating the brittleness of rails, choice will fall on the test bar constituted by a portion of notched rail.

(1) *Stahl und Eisen* for 26 April 1928.

The shape of the notch is the delicate point, because in order to be judicious, the brittleness test should enable the rails to be classed for use in a manner such that the best rails will be reserved for tracks where the traffic is heavy.

It is also found that in service the rails, according to their degree of brittleness, and independently of their chemical analysis, exhibit a greater or lesser tendency to fissure on the rolling surface under the effect of the work hardening, whether followed or not by hardening, resulting from the passage of the loads and above all from the skidding under the action of the brakes [1].

These fissures are developed by intercrystalline progression owing to the brittleness of the mass (figs. 52 and 53) and may lead to sudden fracture of the rail under the passage of a train, as has occurred repeatedly on some foreign railways. That is why the notch ought in some way to deal synthetically with the defect by fissuration.

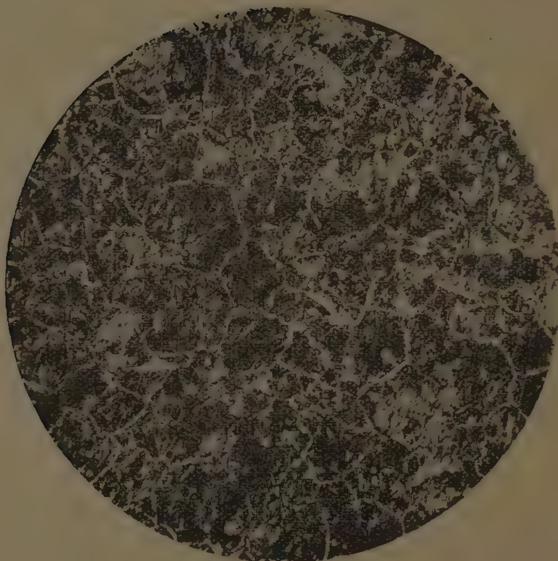
Other railways appear to have adopted our present point of view and we know that the Italian and Swiss railways also use the small Mesnager test piece.

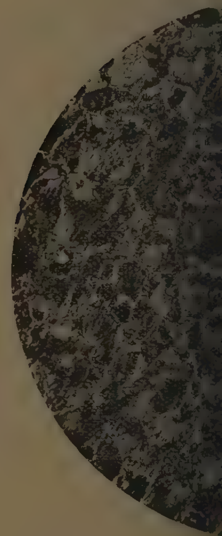
The French railways, while using the Mesnager test piece for their laboratory researches, have prescribed for some years in their specifications, the impact test on a length of rail notched with a milling tool (fig. 54), a 300- kgr. (660 lb.) tup falling from a height of 4.60 m. (15 ft. 1 in.) on a short length of rail with the head in tension; distance bet-

(1) See *Revue de Métallurgie*, September, October, November, 1927; *Revue Générale des Chemins de fer*, November, 1926.

Figs. 39 to 48 (*continued*). — Influence of the final rolli

Head.





50 X.

Fig. 45.

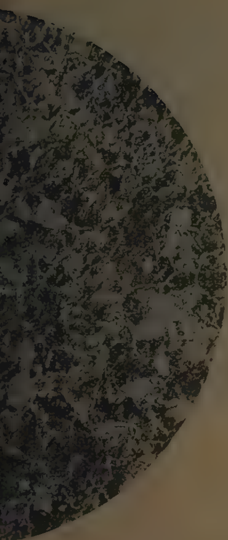
ween supports : 500 mm. (25 7/16 inches) — but the notch made with a milling tool only gives an imperfect significance to this test, since the result cannot be stated in figures and the fracture does not always pass through the notch.

With the object of giving a better definition to brittleness by taking into account the tendency to fissuration, Mr. Merklen, the Special Reporter on the question of rail fractures to the London Congress (1925), the activities of which were concentrated on the rail question, devised a test on a length of rail having a notch 2 mm. (0.079 inch) deep and 0.2 mm. (0.0079 inch) wide, made with a fine saw 0.15 mm. (0.059 inch) thick guided in a frame.

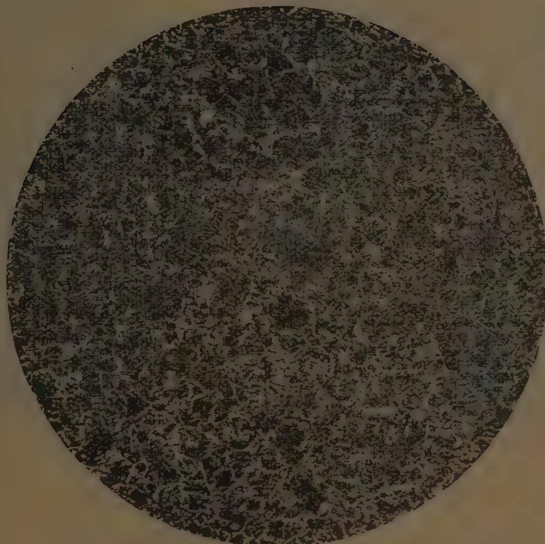
This test is made on a piece of rail 0.70 m. (2 ft. 3 1/2 in.) long, resting on supports 0.50 m. (1 ft. 7 11/16 in.) apart. The first tests were made with ten blows from a 300-kgr. (660 lb.) tup falling through a height of 0.50 m. (1 ft. 7 11/16 in.), the rail being turned after each blow, and beginning with the rail head in tension, then ten blows from a height of 1 m. (3 ft. 3 3/8 in.) in the same conditions, then one blow at 2 m. (6 ft. 6 3/4 in.) rail head in tension, one

ture on the properties of rails, according to Mr. Stumper.

Foot.



50 X.



1150° C.
(2102°F.).

50 X.

Fig. 47.

blow at 3 m. (9 ft. 10 1/8 in.) and so on until fracture.

A number of these tests have been made on our 50-kgr. (100.8 lb. per yard) rails. Some of them broke in the 0.50- m. (1 ft. 7 11/16 in.) series of blows; others in the 1-m. (3 ft. 3 3/8 in.) series; for some of them, although this was exceptional, it was necessary to go to 2 m. (6 ft. 6 3/4 in.).

At the present time, M. Merklen prefers to reduce the number of impacts to two blows alternated in a manner to make the test practical enough for checking brittleness, which should be done on a portion of rail from all the ingots.

This test appears to have the advantage of enabling the rails to be classed in order of their brittleness, without being affected by the various microscopic inclusions which the metal possesses in the different parts of the rail section.

A great many tests will still have to be made before adopting a final attitude. If a test of this type were to be adopted, it would probably be possible to consider granting a rebate to manufacturers for supplies which include a considerable percentage of rails recognised as being non-brittle.

It may be mentioned in passing that, as far as we are concerned, we have been

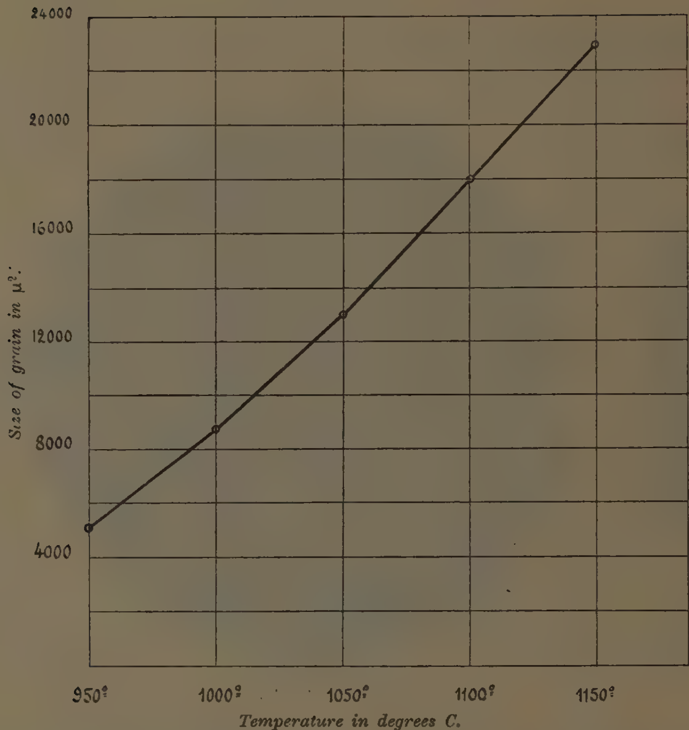


Fig. 48. — *Contd. from figs. 39 to 47*). — Size of grain in relation to the rolling temperature.

in the habit for some years now, of reserving for the tracks where the traffic is intense, perfectly sound rails from ingot bottoms which have given the best test results. Following another line of thought, it is to be hoped that in the near future, it will be possible to estimate in a practical manner the oxygen in steel, and determine exactly its degree of harmfulness and its reaction on the brittleness. As regards brittleness, we shall leave the matter at this point and proceed to the third point, that is to say, the question of the *wear* of rails.

III. — Resistance to wear.

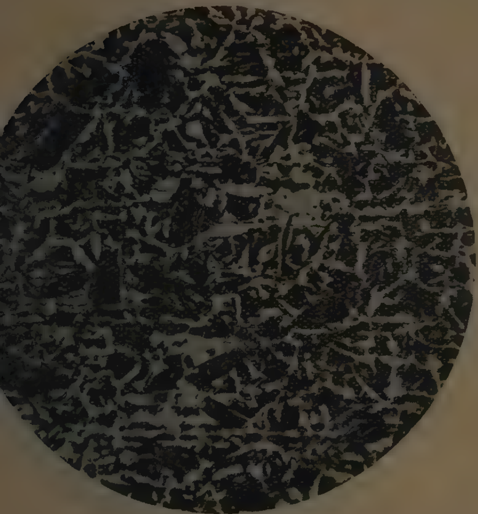
Forms of wear.

The forms of wear which will be discussed are:

1. Wear of the rolling surface by abrasion;
2. Lateral wear of the head of the rail in tracks laid in short-radius curves;
3. Wear by oxidation.

Figs. 49 to 51. — Structure of a rail from an ingot rolled too hot. — Decarburisation of the web.

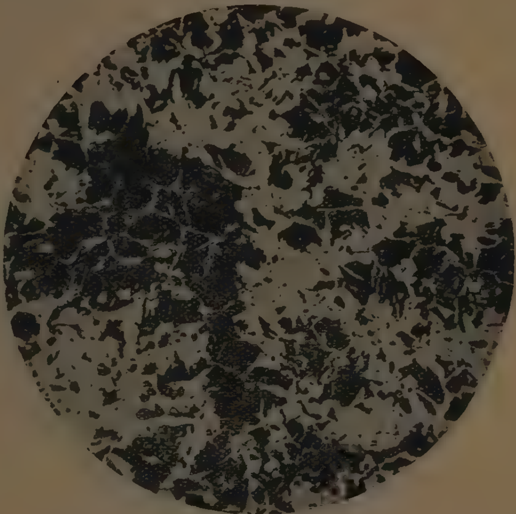
Head.



$\rho = 5.62$ Kg.-M. (40.65 foot-pounds). 100 X.

Fig. 49.

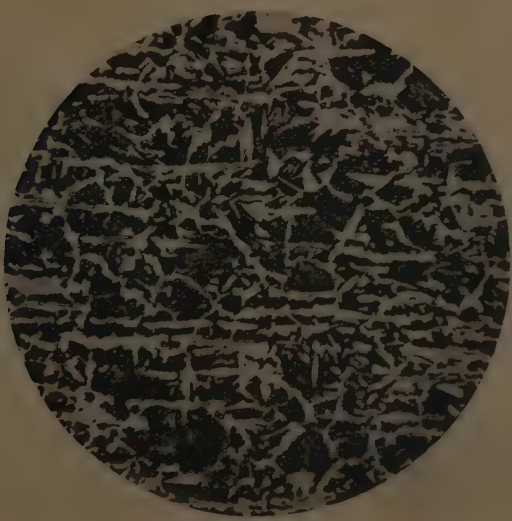
Web.



$\rho = 17.36$ Kg-M. (125.57 foot-pounds). 100 X.

Fig. 50.

Foot.



$\rho = 5.357$ Kg.-M. (38.75 foot-pounds). 100 X.

Fig. 51.

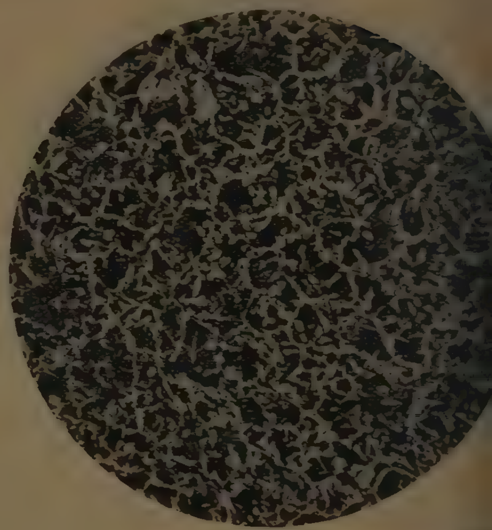
TI—5

Figs. 52 and 53. — Superficial hardening of the rolling surface

100 X.

Rolling surface.

Fig. 52.



100 X.

Centre of head.

Fig. 53.

It may be said once and for all, that rails of sound metal wear more regularly than those contaminated by impurities, which readily give way to local crushing or to flaking (exfoliation).

The first thought which comes to the mind is that, in order to have a metal which will wear well, it suffices to use a hard metal, and for that purpose to increase the carbon content. We have already seen, however, that the result of increasing the carbon content beyond a certain limit is to increase the brittleness. It would appear to be difficult, therefore, to reconcile safety with the point of view of economy.

We find ourselves in a dilemma : under the present traffic conditions, the rails must either be allowed to wear moderately so as to maintain safety, or the resistance to wear must be allowed to come first, while endeavouring to preserve safety by increasing the weight of the rails.

The last solution has been adopted in the United States, where rails are made of open hearth steel having a carbon content of 0.7 to 0.9 % and even 1.0 %, and a weight of up to 67 kgr. per metre (135 lb. per yard).

It appears daily, however, that the policy followed by the great European railways is being shown to be the best.

Moreover, a high carbon content offers

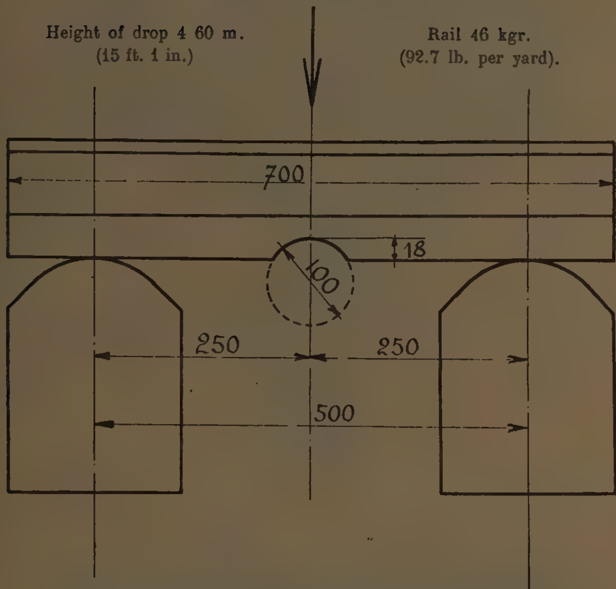


Fig. 54. — Great French Railways. — Impact test on a milled length of rail.

the serious danger of assisting the formation of transverse fissures in the rails (fig. 55 and 56).

The destruction caused by the violent straightening of rails bent in cooling or under a press or in machine rolls, is sufficiently well known. Internal fissures may be formed by this operation and very often very fine cracks are formed in the bull head or flange which are not visible when the rail is inspected. The risks of internal fissuring increase with the hardness of the metal and its lack of uniformity.

Mr. Houbaer, Departmental Chief of the J. Cockerill Company's Steelworks, has said what had to be said on the subject of carbon in his noteworthy paper on the chemical composition of rail steels (1) :

The composition of the rail, he states, as regards carbon, appears to be, and is in fact, solely dependent upon the resistance to wear under heavier and heavier loads. It is therefore this attention to resistance to wear which in most cases, controls the carbon content; as if the rail could indefinitely adapt itself to all requirements, lend itself to all desiderata, without possessing intrinsically of its very essence, some limiting carbon content which a careful railway ought not to exceed in its requirements and which a manufac-

(1) *Revue Universelle des Mines* of 15 January, 1929.

turer ought not to accept as a maximum.

They certainly wish to assume, he continues, that there is a maximum content; for some, it is C=0.50 %; for others, this limiting content lies somewhere between 0.90 and 1.00. As if steel-making, as practised in one country and another, and as if the skill of the metallurgists, varied from one to two.

What would the railway engineers say, he concludes, if the calculation and construction of their locomotives were treated by employing the same principles as basis and simply increasing the carbon content of the various parts as they became more fatigued ?

And yet, in this case, it is a question of parts carefully forged, annealed, treated. What is there to say then of a product used in the raw state of rolling, and work-hardened in places ?

We do not come under Mr. Houbaer's reproach, because we, for our part, have estimated that the carbon content of rails should not appreciably exceed 0.5%. We thus obtain, as we have seen in the table summarising the tests, strengths of 68 to 78 kgr. (43.2 to 51.5 Engl. tons per sq. inch).

The chemical analyses of our rails vary within the following limits :

C. %	S. %	P. %	Si. %	Mn. %
0.40 to 0.52	0.030 to 0.055	0.035 to 0.075	0.12 to 0.25	0.85 to 1.15

It may be stated moreover, that very hard rails (80 kgr. [50.8 Engl. tons per sq. inch]) while being more brittle, do not behave better in wear than relatively softer rails (65 to 75 kgr. [41.3 to 47.6 Engl. tons per sq. inch]).

Under the pressure of the loads transmitted to the rails by the tyres, often made of eutectic steel (0.9 % C.) forged and annealed, the surface layer of the rolling face perishes through successive erosions in the case of the very hard rails, and in the case of the softer rails, considerable cold work-hardening ensues, the depth of which is sufficient to form an adherent and very hard layer, capable of wearing well. The carbon content of many acid Bessemer rails was less than 0.40 % and Brinell hardness figures are found of $\Delta = 286$, corresponding to a calculated tensile strength of 100 kgr. per sq. mm. (63.5 Engl. tons per sq. in.) on the surface of old 38- and 52- kgr. (76.6 and 104.8 lb. per yard) rails, while the hardness figure attains only 187 or less in the head below the cold work-hardened zone, corresponding to an ultimate stress of 65.5 kgr. per mm.^{2} (41.4 Engl. tons per sq. inch) at the most.

For very hard rails : $\Delta = 241$, ultimate stress = 84.1 kgr. per mm^2 (53.4 Engl. tons per sq. inch) for example, the difference is a minimum.

This phenomenon of cold work-hardening and resistance to wear is identical, moreover, with that found in special manganese steels of the Hadfield type, having about 12 % manganese.

These steels possess a hardness which is comparatively low ($\Delta = 202$, ultimate stress = 70.5 kgr. per mm^2 (44.7 Engl. tons per sq. inch) approximately, and only acquire their hard wearing properties after becoming cold work-hardened in service ($\Delta = 400$, ultimate stress = 135 kgr. per mm^2 (85.7 Engl. tons per sq. inch), but the question of rail wear still remains, because in the opinion of the writer, the use of con-

Fig. 55.

Fig. 56.

Figs. 55 and 56. — Transverse fissures.

tinuous brakes on our goods trains will accentuate the wear of our rails owing to the increased speeds and braking zones.

Special steels and heat treatment.

Apart from the ordinary chemical composition as a means for combating wear effectively, there are special steels and heat treatment.

Special steels containing the ordinary elements only, but having higher percentages of certain metals or metalloids, such as silicon steels containing 0.35 to 0.40 % or manganese steels containing 1.5 to 2.0 %, do not constitute in our opinion a sufficiently effective remedy against wear.

On the contrary, those consisting of alloys including nickel chromium, logically require a heat treatment after rolling. We think their price would be prohibitive.

In our opinion, these solutions are only applicable in some special cases; for points, for example, the use of cast steels containing about 12 % manganese has become general.

In this connection, it may be mentioned that we have on trial a level crossing made of nickel-chrome steel.

In making switches, we shall use this year rails of steel made in the electric furnace. This steel has an ultimate stress of 70 to 80 kgr. (44.4 to 50.8 Engl. tons per sq. inch), and its great homogeneity together with its purity leads us to hope for a better behaviour in the track.

There remains the heat treatment of ordinary carbon rails, which appears to hold out good prospects.

In point of fact, this solution is a sure corrective for the hardness of our basic Bessemer steel, and may give very interesting results from the point of view of resistance to wear.

There are various patents in existence relating to the heat treatment of rails. They all have for their object the hardening of the upper surface of the head by a more or less rapid chilling, the residual heat stored up in the entire section being used to lessen the effect of too violent a hardening which might occur.

According as to whether such a system uses air and steam under pressure, immersion only in water for a predetermined time, or short and successive immersions in water, there would be obtained after the treatment, starting from the surface of the head, and extending over a zone, the depth of which would vary according to the treatment, the metallographic constituents : martensite, troostite, troosto-sorbite, sorbite, or the last-mentioned only, passing more or less abruptly into the normal perlitic structure of ordinary steels.

What the heat treatment of rails should effect.

This is not the place to recommend one system in preference to any other. What does interest us, is the programme which is to be carried out, namely :

To give the rail, by means of heat treatment, an accentuated hardness in the zone subjected to wear, so that it may offer sufficient resistance to wear, while improving as far as possible its brittleness figure.

Then again it is necessary to stipulate that the heat treatment should be correct and regular and should act in the direction of safety.

Understood in this way, the heat treatment of rails constitutes, in our opinion, one of the most interesting solutions of the future, and at all events, a very effec-

Fig. 57.

Fig. 58.

Fig. 59.

Fig. 60.

Figs. 57 to 60. — Dinant-Houyet line. — Lateral wear after one year's service.

Explanation of French terms: Rails 50 kgs etc. = 100.8-lb. per yard rails laid in 1928 in a curve of 350 m. (17 1/2 chains) radius.

tive means of improving the basic Bessemer rail of average hardness without incurring any considerable increase in price.

It is a sure means of combating lateral wear of rails in short radius curves and for all places where the ordinary rails would wear too rapidly.

This is a delicate matter, because to consider the problem of wear by regarding the rail only would be a serious error.

All the parts which stress the rail either directly or indirectly should be studied so as to resist or take their relative positions under the best conditions. By this is meant the shape of the rolling surface of the rails, the tyres, bogies and couplings.

Recently, in the course of an enquiry into abnormal rail wear, we found instances of excessive wear on sections of short radius track on the Dinant-Houyet line (figs. 57 to 60).

Lateral wear to this extent, produced in less than a year, constitutes nothing less than a planing away of the surface and cannot be tolerated.

The main cause of this state of affairs

chiefly lies in the stiffness of the heavy rails laid on sole plates, and also in the difficulty of making some locomotives inscribe themselves on the curves.

The use of automatic lubricating devices for the lateral face of the rails and the wheel flanges may form a remedy against these destructive effects, but if these means remain insufficient, it would be better to consider the gradual elimination of the unsatisfactory locomotives as soon as possible, or at least to use them on lines where the curves are not so sharp.

Oxidation.

Against oxidation, from which on the whole we do not suffer very much, it has been recommended to use rails containing copper to the amount of 0.25 to 0.4 %.

We have not tried these steels, but some American Railway Companies and the Italian State Railways have laid, by way of trial, sections of track of copper bearing rails, more particularly in damp tunnels where oxidation is most severe.

It is too early to express any conclusions regarding them.

In general, in order to combat oxidation, most railways have been satisfied hitherto in using rails of heavier section.

RESULTS AND CONCLUSIONS.

In the above, we have confined ourselves to defining the special tests and their results, but no mention has been made of the practical results obtained on rails in service.

In order to complete this report, it may be stated that the statistics kept since 1926, as a result of the resolutions passed by the Railway Congress held in London in 1925, enable us to supply the following information, as regards our railways (see table III).

From the 47.9 fractures per 10 000 000 train-kilometres (6 250 000 train-miles) in 1926, we have fallen to 35.61 in 1928.

It would be very difficult to ascertain the exact proportion of this result which is due to the improvement in the quality of the rails, and that which ought to be attributed to the maintenance of the permanent way and the strengthening of the superstructure. It may simply be stated that the combined efforts of the National Railway Company to remedy the shortcomings of the permanent way have given appreciable results, and that we believe to be the essential matter.

The table giving the percentages of fractures which have occurred at the fishings show that the question of the joint still remains important, owing to the hammering of the rails opposite the fishing joints, and to the settling resulting therefrom. The use of heat treatment of all fishplates certainly constitutes an improvement in the joint but as regards the rails, the capabilities of our industry are such as to enable us actually to consider the supply of a considerable proportion of rails of great length, such as 24 m. (78 ft. 9 in.). This increase would correspond to a suppression of 1/4 of the joints, and would make itself felt in reducing the number of fractures as well as improving the running conditions.

Some railways — in France and Germany — have taken this matter up seriously.

Welding of the rails also offers a solution to the problem of eliminating the joints, and the various tests which have been made in this direction will be followed with interest.

* * *

There is nothing now but to conclude.

A review has been made of the efforts made to improve the quality of rails — efforts which have been dominated by the anxiety in the first place to ensure safety.

The results obtained are encouraging, but merely form, let us hope, a stage towards more marked results.

All arguments on the subject of the different methods of manufacture have been left on one side. Most often, this type of discussion is merely to be regarded as a contest of interests, each country attempting, and quite rightly, to use the raw materials which nature has placed at its disposal in its most immediate vicinity.

As far as we are concerned, it is still our firm conviction that it is possible to manufacture good rails by all the ordinary manufacturing processes, provided the necessary care is taken.

TABLE III.

Years.	Number of metric (*English*) gross tons hauled, passengers and goods.	Number of kilometres (*of miles*) of single track (main lines, in Belgian rails).	Number of train-kilometres (*of train-miles*).	Total number of fractures.	Number of fractures per 10 000 000 train-kilometres (*per 6 250 000 train-miles*).
1926	32 015 981 061 (31 510 320 000)	6 602.288 (4 102.5)	74 817 188 (46 490 060)	359 (1)	47.9
1927	30 268 616 207 (29 790 554 000)	6 632.000 (4 121)	70 260 794 (43 037 420)	297 (1)	42.27
1928	30 627 547 734 (30 143 816 000)	6 749.202 (4 193.8)	69 905 495 (43 438 020)	249 (1)	35.61
1929 (2)	32 888 219 364 (32 368 782 000)	6 827.935 (4 242.7)	74 561 667 (46 331 280)	253 (1)	33.9

(1) These figures include all the *fractures* in ordinary track, excluding track fittings and rails merely split or exfoliated.
(2) The figures for 1929 were added at the time of going to press.

Years.	Type of rails.	Fractures in the fishing joint.	Fractures other than in the fishing joint.
1927	I RL	52.20 %	47.8 %
	II Rm	62.28 %	37.72 %
	III RL	74.47 %	25.52 %
1928	I RL	55.76 %	44 24 %
	II Rm	78.87 %	21.13 %
	III RL	69.64 %	30.36 %
1929 (1)	I RL	54.16 %	45.84 %
	II Rm	78.5 %	26.5 %
	III RL	76.9 %	23.1 %

(1) The figures for 1929 were added at the time of going to press.
I RL = rails less than 42.5 kgr. (85 lb. per yard).
II Rm = rails of 42.5 to 52.5 kgr. 85 to (105 lb. per yard).
III RL = rails heavier than 53 kgr. (106 lb. per yard).

[621. 337]

Individual axle drives for electric locomotives (1),

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Figs 1 to 24, pp. 1611 to 1615.

INTRODUCTION.

Individual axe drive is assuming an ever increasing importance for locomotives using electrical energy as the motive force. This refers both to tractors collecting the electricity while travelling from an overhead conductor or a rail, and to locomotives producing the electrical energy by means of an internal combustion engine, for example. The motion of the armature of an electric motor being rotative, like that of the axles, it is logical to seek to transmit this motion directly, without the agency of connecting rods. There are, however, three special cases where the coupling of three (and exceptionally two) driving axles mounted on the same frame, may offer certain advantages, either from the point of view of adhesion or from the constructional point of view, although these advantages are debated and opinions vary on the subject. These three cases are the following : *shunting* locomotives or tractors which have to develop fairly considerable pulls at a high acceleration without, however, developing high speeds, and for which the use of a single motor is generally more economical; *mountain* locomotives, particularly those intended for work on steep gradients and under difficult climatic conditions; finally, locomotives intended for pulling *heavy goods trains*. The particular working conditions of a given railway will indicate whether it is profitable in the end, with certain types of engines, to arrange for the axles to be coupled in preference to the individual axle drive.

There are, on the contrary, a certain number of cases where individual axle drive is indicated in preference to any other system, the reasons for this being, moreover, very different. In this connection, may be mentioned tramways, rail motor vehicles and very particularly very fast locomotives with a speed of the order of 75 to 150 km (46.6 to 93.2 miles) per hour.

While describing the various systems of individual drive, an attempt will be made to point out their respective qualities and to say a few words regarding the experiments which have been made by the railway companies who have tried or adopted them.

***

The systems of individual axle drive may be divided into four main classes :

a) Motors, the armature of which is mounted on the axle itself, the shaft being common to the armature and the axle, and the motor frame with the poles being suspended from the locomotive frame. This system is called « gearless ».

b) Motors suspended by the nose, commonly known as « tramway suspension »; these motors are suspended from the axle itself by means of two arm-

(1) Translated from the French.

bearings fixed to the motor frame, in which bearings the axle turns, and also at their opposite end from the engine frame (bogie, truck or main frame). This suspension from the frame is generally elastic (springs or rubber pads). This system implies that the axis of the motor should remain at any moment parallel to the axis of the axle.

c) Motors mounted on the engine frame (main frame or bogie frame of a locomotive) and transmitting their power by means of elastic members enabling the shocks of the track and the movements of the wheels relatively to the engine frame to be compensated. We shall call this new category that of elevated suspension motors because they are necessarily placed above the axles.

d) Motors with bevel gear having their axis horizontal, inclined or vertical in a plane at right angles to the axle. This group is sub-divided into motors with vertical axis for very fast locomotives and motors with horizontal or slightly inclined axis used on certain types of trams. The locomotives only will be dealt with.

* * *

The gearless drive (Class A) offers the very great advantage of avoiding gears, but on the other hand, it has appreciable disadvantages : the total weight of the armature is not suspended since it is integral with the axle, from which results the fatigue of the track and of the stock. Owing to the vertical movements of the armature, the air-gap of the two-pole motor has to be large and cannot remain absolutely constant, nor can the brushes remain in the normal adjustment which is best for commutation. The armature forming one piece with the axle and the poles with the engine frame, the maintenance of the motors is a very complicated business.

The first use of gearless drive, made in 1889 on the London Metropolitan Railway (The Underground), had its induction winding also resting on the axle and bearing on the wheels . The whole weight of the motor was thus unsuspended and the wear and tear of the stock and of the track was excessive, so that this application was very soon abandoned.

The gearless system is very interesting, however, and has been developed considerably in America, since the time of the patents taken out by J. Batchelder, who had the idea of transferring the induction winding to the engine frame. Since 1906, this system has been used by the « General Electric Company » of Schenectady, N. Y., on important groups of locomotives, namely 83 gearless engines, all having four driving axles, on the New York Central Railroad, of which a set of 35, type $2D_02$, was fitted as long ago as 1906. The Baltimore and Ohio Railroad had three gearless, type B-B, engines in service in 1895, but these engines have now been withdrawn from service as being of a type which is too obsolete. All these engines were built for D. C. at 600 volts.

In 1919, the Chicago, Milwaukee, St. Paul and Pacific Railway put into service 5 engines with 12 driving axles, of the type $1B_0+D_0+D_0+B_01$, of 4 000 H.P., hourly rating, for D. C. at 3 000 volts. The mechanical parts of the gearless locomotives are constructed by the American Locomotive Company.

Only one application has taken place in Europe, and it is that of the high speed locomotive No. 601 of the Paris-Orleans Railway, an engine which has also been constructed by the General Electric Company, and is described by

H. Parodi in the August, 1927 number of the *Revue Générale des Chemins de fer*. The writer considers that it would be premature to make a definite statement as to the actual value of this system, in view of the few occasions on which it has been used recently; the use of the system on the Paris-Orleans does not as yet allow any conclusions whatever to be drawn.

Purely as a historical matter, it is interesting to mention at this point the gearless hollow shaft drive, in which the armature is keyed directly on a hollow shaft surrounding the axle shaft. The armature, that is to say, the hollow shaft carries pins which drive the axle through articulated couplings. A brief description will be given in what follows of the oldest and most characteristic construction of this system of drive (from which construction, moreover, most of the mechanisms in use at the present time for individual axle drive are derived), the articulated coupling which the Ganz Works of Budapest applied in 1902 to the 4-axle, type B_0—B_0, group E334 locomotives, for three-phase current at 3 000 volts and 15 cycles, of the Valteline Railway (Italian State Railways).

Another construction which may be mentioned, but which will not be described here is that which the Westinghouse Electric and Mfg. Co. of East Pittsburgh (Pa., U. S. A.), applied in 1907 to 41 locomotives of the $1B_0$—B_01 type on the New York, New Haven and Hartford Railroad, the maximum permissible speed of which is given as 140 km. (87 miles) per hour; the mechanical part of these locomotives was made by the Baldwin Works of Philadelphia (Pa.). For the purpose of refreshing the memory, mention may also be made of the system used in the trials of 1901 to 1903 on the special three-phase motor vehicles, constructed by the German firms, the A. E. G. and Siemens-Schuckert, for a speed of 200 km. (124 miles) per hour, on the test line from Marienfelde to Zossen; the A. E.G. rail motor vehicle was fitted with a drive consisting of semi-elliptical leaf springs, placed back to back in pairs, fixed radially near the hub and acting on the periphery of the wheels by their flexible ends.

Figure 1 shows the above-mentioned articulated coupling of the Ganz Works. M is the motor, rigidly fixed to the main engine frame. The armature is keyed on the hollow shaft W surrounding the shaft A of the axle. The end of the hollow shaft is provided with two arms K_1 and K_2, to which are attached, by means of the pins Q_1 and Q_2, two small driving rods Z_1 and Z_2. The other ends of the said rods are connected at U_1 and U_2 to two bellcrank levers H_1 and H_2. The two bell-crank levers pivot about two pins P_1 and P_2 fixed to the spokes S_1 and S_2 of the driving wheel R. The other ends T_1 and T_2 of the bell-crank levers H_1 and H_2 are connected together by a connecting rod G.

The turning moment is transmitted as follows : when the armature rotates in a counter-clockwise direction (see the figure), the bell-crank levers H_1 and H_2 are compelled to turn in different directions relatively to each other about their pivot pins P_1 and P_2. Owing to the rod G connecting the pins T_1 and T_2, the two bell-crank levers can only turn in the same direction about their pivot pins, and consequently, the reactions produced on the pins P_1 and P_2 impart a movement of rotation to the driving wheel in the same direction as that of the hollow shaft. If, on the contrary, the hollow shaft moves parallel to itself, the bell-crank levers H_1 and H_2 are obliged to turn in the same direction

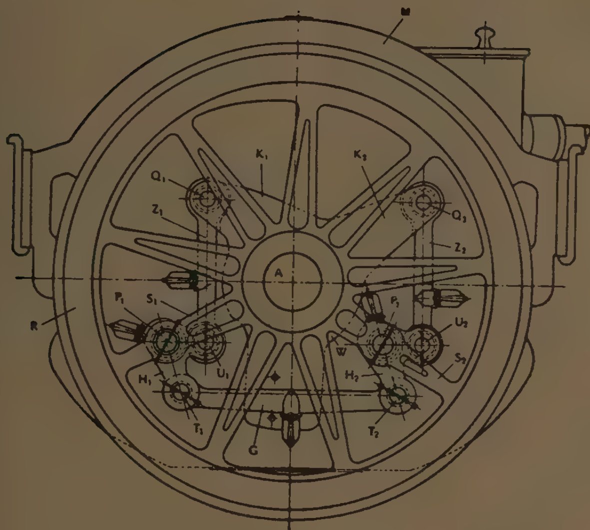

Fig. 1. — Articulated coupling of the Ganz Works, Budapest (1902).

relatively to their pivot pins P_1 and P_2, which movement is allowed and controlled by the connecting rod G. The joints Q_1, Q_2 and U_1, U_2 are provided with spherical bearings, in order to allow of angular movements between the axle and the hollow shaft carrying the armature.

It is easy to find a direct relationship between the working of this mechanism and that of several of the systems of individual axle drive which will be described in the course of this paper.

* * *

The *tramway suspension* motors (Class B) constitute the system of individual drive which is most commonly used. It is not the writer's intention to describe here the modifications of this system, regarding which complete details will be found in the technical literature. Almost all the tramways of the whole world and the very great majority of rail motor vehicles are equipped with motors suspended by the nose. In addition, a large number of companies also use this system for certain types of locomotives, whatever be the gauge. The French Midi and the Paris-Orleans Railways employ chiefly BB engines (more correctly, B_0+B_0), and use them frequently up to 90 km. (56 miles) per hour; the State Railways also employ them for part of the electric services of the suburbs of Paris. The Paris-Orleans, in addition, is carrying out a trial for speeds up to 110 km. (68.3 miles) per hour (variation of gear ratio) with some of these locomotives; as for the Paris-Lyons-Mediterranean Company, they are employing, in addition to others, a certain number of engines for goods trains of the type

$1C_0+C_01$, tram suspension motors, speed, 80 km. (50 miles) per hour. In Spain likewise, the North Railways (Caminos de Hierro del Norte) already possess about fifty 6-axled locomotives (types $C_0—C_0$, series 6 000 and 6 100, C_0+C_0, series 7 000 and $1C_0+C_01$, series 7 100), with tram suspension motors, the most recent series of which can travel at 110 km. (68.3 miles) per hour. The German State Railways are conducting a test, among others, on express engines of the type $1B_0+B_01$, likewise with tram suspended motors, designed for a maximum speed of 110 km. (68.3 miles) per hour : this Administration has not yet issued any statement regarding the result.

As regards rail motor vehicles, this system is commonly employed for speeds of up to 100 km. (62 miles) per hour.

The uses of the tram motor form a very extensive subject, which will not be dealt with at this place; the writer has merely restricted himself to mentioning a few large-scale constructions for high speeds, and he would like to repeat that, in his opinion, this system implying that half the weight of the motors is not suspended but is supported rigidly on the axles themselves, must necessarily fatigue the track and the stock much more than other systems with motors completely suspended. It is evidently difficult to form an exact opinion on this subject, a decisive test being practically impossible to make under working conditions. It may be admitted, however, that the destructive effect of the tram system, as well as in fact that of the gearless system, is less than that of steam locomotives, chiefly on account of the vertical components of the forces developed by the moving masses. A great drawback of tram suspended motors is that it is impossible, without taking down either the motor or the axle, to separate mechanically the motor from the axle in case of an accident occurring while making a run. Most of the systems of individual axle drive which will be described in this paper allow this mechanical separation to be performed in a very simple manner, provided they are designed for this purpose. It is certain, on the other hand, that the very great simplicity of the tramway suspension and its ease of upkeep compensate for other drawbacks.

The examination which will be made in this paper thus amounts to a treatment of the aforementioned classes C and D, and more particularly from the standpoint of European practice.

* * * *

As a classification, the systems will be taken in the order of the number of their applications, taking into account, however, the date of their introduction. Afterwards, the writer will content himself with mentioning those systems which up to the present have only had a single experimental application. No reference will be made to those systems which have not been used.

CLASS C.

The system of axle drive which is certainly the most widely used is that of the Brown-Boveri firm, also known as the « Buchli » drive, after the name of its inventor, the engineer J. Buchli of Winterthur. More than 250 electric locomotives, of which, it is true, more than four fifths are in Switzerland, the country of origin, are equipped with this system of axle drive. It has been standardised for the express locomotives of the Swiss Federal Railways, single-phase current, 15 000 volts, low frequency of

16 2/3 ∿, series 10601 (type $2C_01$) and 10901 (type $2D_01$), for several years already. The same applies to the State Railways of the Dutch East Indies express locomotives, type $1D_01$, series 3001 (D. C., 1 500 volts), where four locomotives fitted with this system are in service on the Batavian railways [1]. In addition, large classes of these locomotives are in service in Germany, as also on the North of Spain Railways, which will be referred to later.

The following is a brief description of this system of individual axle drive, the most common construction, that of a drive acting from one side only, is shown in figure 2.

The main gear wheel is placed outside the axle and on one side only, suspended in overhung fashion on the end of the shaft round which it turns, the said shaft being integral with the main frame of the engine. This gear wheel is provided with two pins to be seen in its lower portion (elevation and section, figure 2). Two double levers, movable about these pins, are connected together by toothed segments, while the outer ends of the levers are connected by means of small rods on spherical bearings to two pins secured to the driving wheel, and visible in the figure in the uppeer portion of the wheel; these two pins pass through two sufficiently large openings provided in the inner side of the body of the gear wheel. This arrangement enables the gear wheel to be placed eccentrically relatively to the normal position of rest of the axle (see fig. 2), the toothed segments, when the axles are rotating during running, compensating not only for the vertical displacements of the axle relatively to the locomotive frame, but also the eccentricity of the gear wheel. This enables the gear wheel to be placed higher in those cases where, in its normal position, it would encroach on the loading gauge. It is clear, on the other hand, that the wear of the driving members necessarily depends upon the degree of eccentricity.

Apart from the applications on a large scale already mentioned, test locomotives, one or two engines, are in service on various railways; they are mentioned in the following, in which connection it should be noted that the powers given are per hour, on the wheel tread and for an average line voltage of 1 350 to 1 400 (or double for systems of 3 000 volts D. C.) :

a) Two locomotives, type $2\text{-}D_0\text{-}2$, series 501, 3 600 H. P. speed 130 km. (81 miles) per hour, of the Orleans Railway Company (P.-O.) (D. C., 1 500 volts, standard gauge of 1.435 m. = 4 ft. 8 1/2 in.) (see the article by H. Parodi in the *Revue Générale des Chemins de fer* for July, 1927).

b) Two locomotives, type $1D_01$, series 7001, 2 200 H.P., speed 100 km (62 miles) per hour, in Japan, Japanese Government Railways, (D. C., 1 500 volts, gauge of 1.067 m. = 3 ft. 6 in.) (fig. 2).

c) Two locomotives, type $1D_01$, series E. 465, 1 800 H.P., speed 90 km (56 miles) per hour on the Czechoslovakian State Railways (D. C., 1 500 volts, standard gauge).

d) One locomotive, type $2\text{-}C_0\text{-}2$, No. 4002, 2 200 H.P., speed 120/135 km. (74.6/83.9 miles) per hour, on the Great

(1) See the *Bulletin* for February-March, 1929, of the Société Belge des Ingénieurs et des Industriels, Brussels, pages 142 145, the *R vue Générale des Chemins de fer* for May, 1928, page 378, and the periodical *Elektrische Bahnen*, Berlin, number for November, 1928, pages 340-342

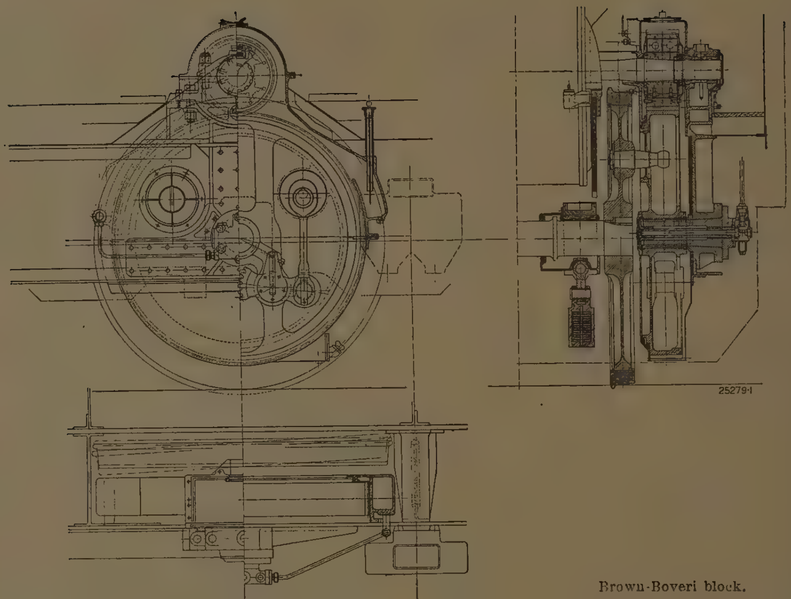

Fig. 2. — Brown-Boveri individual axle drive. (Japanese Government Railways, series 7001) (similar to the standard construction in Switzerland and in the Dutch East Indies).

Indian Peninsula Railway, at Bombay (Indian State Railways main line electrification), (D. C., 1 500 volts, gauge of 1.676 m. = 5 ft. 6 in.).

e) One locomotive, type $1D_01$, No. 231, 3 200 H.P., speed 105 km. (65.2 miles) per hour, on the Paulista Railway in Brazil (D. C., 3 000 volts, track of 1.600 m. = 4 ft. 11 in.).

f) One locomotive, type $1D_01$, test engine, 1 000 H. P., speed 70 km. (43.5 miles) per hour, on the Circumvesuvian Railway, at Naples, (D. C., 1 200 and 2 400 volts, track of *950* mm. = 3 ft. 1 3/8 in.) gauge only.

The $1D_01$ engines mentioned under *b*), *c*) and *e*), as well as those of the State Railways of the Dutch East Indies previously mentioned, may also be referred to as being of the type 1A-AA-A1 (or $1A\text{-}A_2\text{-}A1$), which term denotes the combination in bogies of external driving axles with carrying axles.

The power developed per driving axle varies, according to the type and gauge between 250 and 900 H.P.; in most cases, there is only one motor per axle; rarely, as for example, for the Paulista and the Great Indian Peninsula, there are two twin motors per axle. It is interesting to note also that in the construction applied to the high speed engines of the Paris-Orleans and the North of Spain Railways, likewise previously mentioned, the axle drive is effected from *both* sides,

the traction motors having a pinion on each end of their shaft. The $2\text{-}C_0 + C_0\text{-}2$, series 7201 locomotives of the North of Spain have this feature, that in spite of the very wide gauge of 1.674 m. (5 ft. 6 in.), they have the frame outside the wheels; on account of this, the pivots of the driving wheels, to which the power is transmitted by means of the rods of the drive, face inwardly instead of outwardly, and consequently, the two gear wheels are also of necessity situated within, say between the driving wheels, which requires the presence of a cylindrical tube (a hollow non-rotary shaft) surrounding the axle shaft.

Unlike most of the other constructions with hollow shaft, it is here a question of a fixed tube which does not rotate with the axle, but is rigid relatively to the main engine frame and to the motor frame, being integral with these two parts. The two gear wheels form a bearing at their centre and rotate about the ends of this tube. These two gear wheels are each driven by a pinion on either end of the armature shaft. The drive mechanism in itself is, moreover, entirely unchanged; it is clear that, in this case, the gear wheels are secured in a much more satisfactory manner than in the normal system, where the gear wheel is supported on one side only and in an overhung manner, as in figure 2. The power per hour at the tread rim of these locomotives of the North of Spain is 3 200 H. P., and they are built for a maximum speed of 110 km. (68.3 miles) per hour, a remarkable figure considering the very large number of gradients on this railway. The North of Spain modification of the Brown-Boveri drive, as compared with the outside drive of the wheels, possesses the advantage of avoiding the eccentricity of the gear wheels with respect to the axle, usually necessary on account of the limit imposed by the clearance. The closing of the openings required for the passage of the pivots through the gear wheels is much more satisfactory and is much easier to maintain when the gear wheel is concentric with the driving wheel.

In what follows, what appear to be the particular advantages of the Brown-Boveri system will be pointed out, as well as its disadvantages, and what experiments have been made by the railways making use of it. Apart from the exceptions which have just been mentioned in connection with the Paris-Orleans and the North of Spain, all the other constructions have the axle drive on one side only, outside the driving axle as shown in figure 2 [1]. At the beginning and with the first constructions, fears were entertained by some on the subject of certain points which appeared to be delicate, particularly the external overhung suspension of the large gear wheel, the armature supported in *three* bearings, the short distance between the upper portion of the tyre and the armature shaft (see fig. 2), and finally, the torsion couple of the axles, owing to the drive acting on one side alone. None of these drawbacks has made itself felt in practice, however; the construction of the Paulista locomotive, already mentioned previously, is particularly interesting in this connection, because it transmits per driving axle on one side alone 800 H.P. (two twin motors). The additional weight placed on the one side by the axle drives of all these engines is compensated for by all

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[1] The locomotive mentioned under *f*, of the Circumvesuvian Railway (Strade Ferrate Secondarie Meridionali, Napoli), however, has the gear wheel *between* the axle wheels, against one of the wheels.

the mechanism concentrated in superimposed stages on the opposite side of the locomotive , that is to say, on the side where the wheels are perfectly free towards the outside.

The writer considers that one of the main advantages, if not the greatest, of this system of axle drive applied on one side only is that it not only makes the motors and mechanism very accessible. but also makes it possible to supervise the whole of the electrical equipment directly from the door of one or the other driver's cab. With the object of illustrating this arrangement clearly, a photograph is reproduced in figure 4, showing the interior of the locomotive, the view being taken along the main corridor (on the side of the axle drives) and providing some idea of the distribution of the electrical equipment; excellent accessibility to the mechanism is obtained either by means of the transverse corridors between the motors, or from the outside through small doors in the locomotive body on the side opposite from that of the axle drive.

It will be seen also that the accessibility of the motors, the collectors, the gears and the drive is excellent. These advantages of accessibility and supervision are the indirect advantages of this system; as direct advantages one may mention the possibility of eccentricity of the gear wheel relatively to the axle (fig. 2), and the considerable flexibility in all directions of this drive, which flexibility enables, in particular, the tractive effort of the motor, fixed in the main frame, to be transmitted to a driving axle combined in bogie with the carrying axle, and consequently being able to turn about a fixed point. On the other hand, an appreciable disadvantage, which is not moreover inherent to this system alone, but may be seen in numerous types of locomotives, particularly having coupled axles, lies in the fact that in order to remove a motor from the locomotive, it is necessary partly to dismount the locomotive or at least to remove part of the roof.

A certain number of locomotives with axle drive on one side alone, have been provided with « Java » type bogies, connecting the carrying axle with the outside driving axle, and which has been described by the present writer in the May 1928 number of the *Revue Générale des Chemins de fer*, already mentioned, pages 379-380, figures 5 and 6; to be mentioned are the locomotives of this type in the Dutch East Indies (first application discovered by the writer in 1922, whence the name of Java), in Czechoslovakia, in Japan, by the Paulista Railway, and also partly by the Swiss Federal Railways (see below). In Germany, the arrangement of the bogie is similar to the Krauss-Helmholtz system. In all these constructions, the motor (single or twin) is fixed in the main frame of the locomotive and the drive is transmitted from the large gear wheel, likewise fixed relatively to the frame, to the driving wheel movable with the axle.

The chief drawback of the Brown-Boveri system lies in the fact that it is difficult to close in a reliable and lasting manner the openings of the gear box, which are rendered necessary for inserting the pins in the wheels and connected to the driving rods; the movements of the axle relatively to the frame, as also the eccentricity, require these openings to be comparatively wide (see figure 2 and the upper left hand quarter of the wheel in figure 3). Another drawback of this system lies in the fact that it is practically inapplicable (and in fact has never

been applied) to goods engines, the gear ratio necessitating in that case too great an eccentricity with respect to the wheel diameter, or encroaching downward on the clearance gauge. One may mention still further, as a disadvantage of this system, as compared with others, considered altogether relatively, moreover, the spherical bearings (necessitated by the flexibility in all directions, which is, in its turn, an advantage of the system, as already mentioned), which require a complicated system of pressure lubrication ; various other systems, however, possess this disadvantage, but perhaps in a less pronounced degree. In addition, since the moment of rotation is transmitted rigidly from the axle to the gear wheel, it is necessary to provide the pinion with a rim which is flexible relatively to its hub, evidently a complication from the point of view of construction and maintenance. Finally, the system, at least when the drive is transmitted on one side only, requires the armature shaft to be supported in three points, by three bearings (the two shield bearings of the motor, and the outer bearing on the gear, a shaft end projecting beyond the pinion, see fig. 2) which is statically unstable; experience has shown, however, that no drawbacks while running have resulted from this fact either. Last of all, it may be stated that upkeep is expensive, owing to the comparative difficulty of assembling all the parts.

The Swiss Federal Railways (C F F), possess at the present time in their equipment of electric locomotives, more than 200 engines fitted with the Brown-Boveri drive, all built by the Winterthur Locomotive Works (the electrical equipment of most of these engines is that of Brown-Boveri, others are of Oerlikon, and some of Sécheron (of Geneva). Of the number mentioned, more than 100 locomotives of the 2-C_0-1 type (designation CFF Ae 3/6 I, series 10601), and consequently having three driving axles, power per hour 2 000 H.P., speed 90 km. (56 miles) per hour, have now had at least three years' service and have run at least 100 000 km. (62 100 miles). The first locomotives of this type were put into service in 1921 and have been running therefore for nine years. In addition, the Swiss Federal Railways also possess, forming part of the 200 above mentioned, a large series of 2-D_0-1 type locomotives (Ae 4/7, series 10901), with four driving axles, power per hour of 2 700 H. P., speed of 100 km. (62 miles) per hour, of which forty new ones will be built in 1930; 22 of these engines have likewise been fitted with a modified « Java » type of bogie, on the back unsymmetrical side where the single carrying axle is combined in a bogie with the No. 4 driving axle (this particular type is in consequence denoted by 2-A_3-A1); on the front side, the engine has a double-axled carrying bogie, mainly supporting the weight of the transformer. Figures 3 and 4 refer to locomotives of these types.

The trials made by the Swiss Federal Railways with this system of drive have certainly been very satisfactory, since these Railways have been induced to standardise this type. The only reproach which the Swiss Federal Railways make lies in the difficulty of satisfactorily closing the openings, the dust and foreign bodies which find their way in, causing in time rather considerable wear of the spherical bearings of the rods.

The railways, which after the Swiss Federal Railways, possess the greatest number of engines with the Brown-Boveri individual axle drive are the Deutsche Reichsbahn-Gesellschaft (German

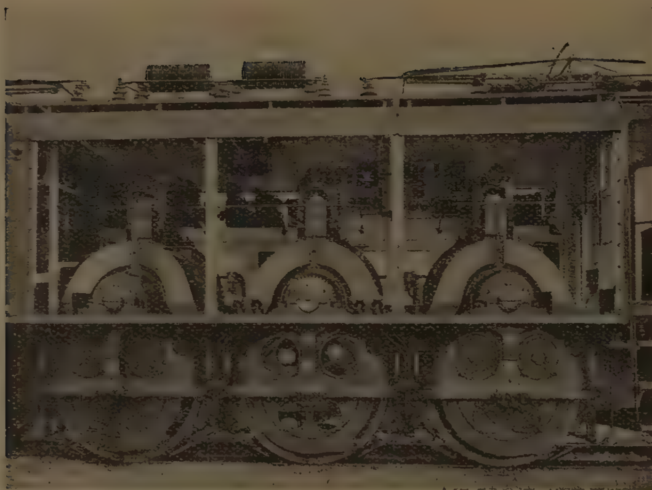

Fig. 3. — Standardised locomotive, type 2—C_0—1, of the Swiss Federal Railways. Axle drive side, sides removed.

Fig. 4. — Interior view of a standardised locomotive, type 2—D_0—1, of the Swiss Federal Railways; longitudinal corridor on the side of the axle drives.

State Railways), already mentioned. At the present time they possess 17 locomotives of the $1D_01$ type (or more exactly, 1A-AA-A1), series 16 (No. 16.01 and the following) of which ten have been in service for nearly four years and seven are of recent construction. These engines are perfectly symmetrical, with transformer in the middle (single phase, high tension, low frequency) and have the carrying axle combined with the driving axle in a Krauss-Helmholtz bogie. The Management are very satisfied with the trials made so far with this system of axle drive. These locomotives have been built by the Brown-Boveri works at Mannheim as regards the electrical parts, and by the locomotive works of Krauss and Co., at Munich as regards the mechanical parts.

The trials made in the Dutch East Indies have likewise been very satisfactory, since as has already been mentioned, they have resulted, as in Switzerland, in the standardisation of the Brown-Boveri system of drive for the express locomotives. The disadvantage of the closing of the openings for the driving pivots has made itself less felt in Java than in Switzerland : the first two engines 3001 and 3002 have been in service for almost 5 years and each of them has already run over 100 000 km. (62 100 miles).

Finally, on the Paris-Orleans, the system has also given very good results, and the engines are working to the complete satisfaction of the technical departments of the Company. At the present time, these two locomotives have run nearly 400 000 km. (248 400 miles). As regards the other test engines which have been mentioned, they appear to be giving good results everywhere.

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*

The axle drive, which after the Brown-Boveri drive has had the greatest number of applications (also about 240 locomotives, including the American engines) is the *Westinghouse quill drive*. The axle on the left of figure 5 shows this drive in its original form, in which it was applied in the United States by the Westinghouse Electric and Mfg. Co., then in Europe on an express locomotive of the North Eastern $2\text{-}C_0\text{-}2$ type (England), and by the Société anonyme des Ateliers de Sécheron of Geneva for 43 locomotives of three different types ($1B_01 + B_01$, $2\text{-}C_0\text{-}1$ and $1\text{-}C_0\text{-}1$, respectively, Be 4/7 I, Ae 3/6 III and Ae 3/5 I), provided by this firm for the Swiss Federal Railways.

This drive, as also others derived from it, to be described later, implies an outside frame and requires the provision of a hollow shaft in which the axle rotates : on the hollow shaft itself, which transmits at both ends the driving couple to the wheels, is mounted the main gear wheel (or the two gearwheels, if gearing on both sides is required, a point which is regarded differently by different undertakings). The entire mechanism formed by the hollow shaft, its transmission arms and the gears, turns in bearings provided for the purpose in the lower portion of the motor frame, generally provided in the form of a twin motor. The ends of the hollow shaft are provided with plates, to the number of six, which penetrate between the spokes of the wheels; dishes in which are held the springs are secured to these plates, each dish being secured by means of an arm and three bolts (shown very clearly in figure 5 near the hub). The other ends of the springs rest on corresponding dishes secured by two bolts to the spokes themselves of the driving wheels. All the springs, therefore, are always stretched only in one direction of running, and are compressed only in the other direction, which results in fatigue of the ma-

terial already reflected in the breaking of many springs.

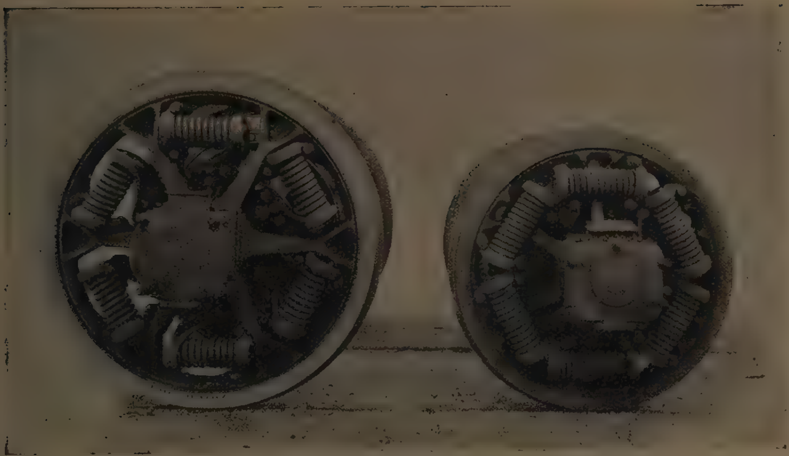
A modification of this system is that shown on the right of figure 5, which was patented by the previously-mentioned Ateliers de Sécheron. It will be seen that three points only (instead of six) connect the ends of the hollow shaft to the driving wheel through interposed springs. These three points of attachment are each connected by two springs, on both sides (therefore symmetrically with respect to the two running directions) to three fixed points on the driving wheel; in this way, of two twin springs, one is always in tension and the other always in compression for the same running direction, and *vice versa* for the other direction. The effort of a driving point is therefore now always distributed over *two* springs; in addition, in this new construction, the springs may be made longer (number of coils). The essential difference between the system shown on the left of figure 5 and that on the right, lies in the fact that each point of attachment does not support one spring alone, starting in the same direction, but, as already mentioned, two springs acting both ways. This modified system was used for the first time with considerable success on the large mountain locomotives, type $1\text{-}C_0+C_0\text{-}1$, series 201, 4 500 H. P., hourly rating, speed 75 km. (46.7 miles) per hour, supplied by the Ateliers de Sécheron, of Geneva, to the Bernese Alps Railway Company, *(Berne - Lötschberg - Simplon)*, Switzerland, singlephase, 15 000 volts, 15 cycles, standard gauge, twin motors mounted on the bogie frame, axles driven by two gear wheels placed at both ends of the hollow shaft, with helical teeth (see fig. 7). Two engines of this type have been in service for several years and work a heavy traffic; the mechanical part of these locomotives was constructed by the Ernesto Breda per Costruzioni Meccaniche Company of Milan.

Another interesting application, although a single one is that of the small $B_0\text{-}B_0$ mountain locomotive of the Bernina Railway in Switzerland [long gradients, 1 in 14.3, by adhesion on a metre track in the high mountains, highest point 2 256 m. (7 400 feet), consequently very difficult adhesion conditions especially in winter].

Finally, 29 locomotives of the Austrian Federal Railways (single phase, 15 000 volts, 16 2/3 cycles, normal gauge), B_0+B_0 type, series 1 170, 1 360 H. P., speed 60 km. (37.3 miles) per hour, passenger train locomotives, have been fitted with this system with perfect success. These engines, which were supplied by the Elin Company (mechanical part by G. Sigl Locomotive Works, Wiener Neustadt, and the Wiener-Lokomotiv-Fabriks of Vienna-Florisdorf), have also been constructed with gears on both sides. As shown in figure 6, the gearing is helical and in different directions on both sides, as moreover for the Lötschberg locomotives.

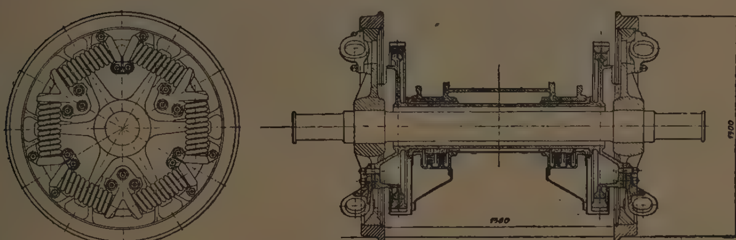
The motors, which in this case are single and not twin, that is a single motor per axle, carry the hollow shaft in their bearings which are integral with the motor frame; their axis is not in the vertical plane of the axle, but is displaced relatively to the axle towards the interior of the bogie, and are rigidly secured to the bogie frame. This special arrangement, which offers some resemblance to a bogie with two tram suspended motors, does not in the least alter the system of drive.

It appears that the Sécheron modified drive has given better satisfaction in running than the original quill drive, the Austrian Federal Railways, and the



Sécheron block.

Fig. 5. — On the left : Driving axle equipped with the Westinghouse quill drive; on the right, the Sécheron drive mechanism.



Elin block.

Fig. 6. — Driving axle of the series 1170 locomotives of the Austrian Federal Railways. (Same drive as on the right of fig. 5 and in fig. 7, Lötschberg locomotives).

Fig. 7. — Driving bogie of a 200 series locomotive of the Lötschberg Company.

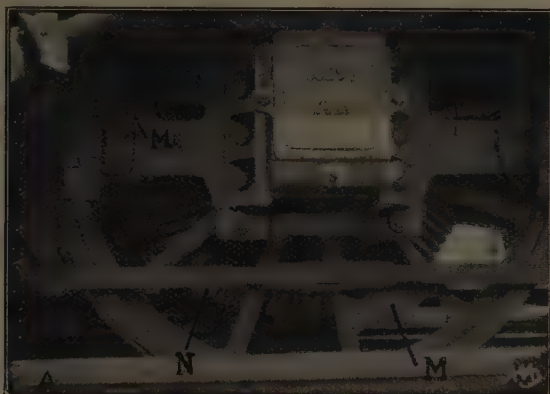
Lötschberg Company being very satisfied with this drive, which also possesses the advantage of allowing of a smaller diameter for the driving wheels than does the quill drive; the smallest diameters which are constructionally permissible for the two systems are about 1.600 and 1.350 mm. (5 ft. 3 in. and 4 ft. 5 5/32 in.) respectively. The writer also believes that the quill drive (and obviously also its modifications) is the one giving the best adhesion conditions, especially for mountainous and winter service. In fact, as soon as one of the pairs of wheels begins to slip, the springs are immediately relieved of load and give, which forthwith brings the traction effort below the limit af adhesion. At this moment, the other pairs of wheels are induced to slip in their turn. Thus, at the beginning of starting, a sort of rolling is set up among the pairs of wheels commencing to slip, and generally, the engine gets well under way before any pair slips to a serious extent.

In this connection, the present writer has been able to make numerous observations on the previously mentioned large engines of the Lötschberg, which up to quite recently were the most powerful in the world, and which have a very heavy service to perform in hauling, and even starting, loads of up to 550 and 600 tons on gradients up to 1 in 37. The question of adhesion being itself intimately bound up with the individual axle drive, the following statements regarding these Lötschberg engines should prove of interest.

As may be seen in figure 7, these locomotives were equipped at the outset, as is still generally the case, with several sanders, by which sand could be projected under each driving wheel, and in each of the two running directions. Now it is known that when in service, the sanding gear of electric locomotives frequently works badly, which has also been the case on the Lötschberg Railway, especially in winter. Experiments made during running led the Lötschberg Company to do away with all the sanders (16 in number, 8 of which being double) fixed between the wheels to the bogie frame, and to replace them by two large sanding devices only, fixed to the back wall of each of the two driving cabs. Each of these two sanders supplies sand to the *first driving axle* alone of the locomotive, in each running direction, and this has proved perfectly sufficient, especially during the winter of 1928-29, which was exceptionally severe.

For the sake of completeness, reference ought to be made at this point, before proceeding to the third modification of the quill drive, to two other particular constructions, one used on the French State Railways, and the other on the Paris-Lyons-Mediterranean Railway. The old B_0-B_0 rail motor vehicles, series 5001, put into service in 1899 by the Compagnie des Chemins de fer de l'Ouest, now the French State Railways, for their lines in the suburbs of Paris and more particularly for the tunnel on the Invalides-Versailles line, were constructed for D. C. at 500 volts, third rail, and are still at work, under 650 volts, after 30 years' service. Their drive mechanism, which is on alternate sides for each axle, except for a few details, is the same as the present patented Sécheron arrangement. A hollow shaft, at one end of which is mounted a triangle perpendicular to the axle, surrounds the axle shaft. This hollow shaft, on the first engines supplied by Westinghouse, turns in the bracket bearings of the motor frame; in the later engines, the electrical equipment of

which was supplied by Brown-Boveri, the hollow shaft forms the armature shaft itself. The mechanical part of the rail motor vehicles was supplied by the Baume and Marpent Works. In its first form (Westinghouse) this mechanism could also be classed under a special heading in the « tramway suspension types » and in its second form (Brown-Boveri) in the category of « hollow shaft gearless ». The three apexes of this triangle each carry a pivot pin N (see fig. 8) parallel to the shaft and pointing outward. The axle wheel, near the triangle also caries three similar pivot pins M, directed inwardly, the six pins,



A. Hug photo.

Fig. 8. — Axle and drive of a series 5001 rail motor vehicle of the French State Railways.

when the machine is at rest, being located on the same concentric circle as the axle and the hollow shaft; consequently, the six pins alternate from the triangle to the wheel, and each is connected to the pivot pins on either side by a pair of helical springs. Each spring, visible in the figure, has within it a spring of smaller diameter coiled in the opposite sense, and is thus double. The end of the hollow shaft opposite the triangle carries the gear wheel which meshes with the pinion. This device (which appears to have been, for the Westinghouse firm, a forerunner of the quill drive) provides a very flexible transmission, but causes frequent breakage of the springs, the latter being subjected successively or simultaneously to compression, tension, bending and finally torsion. It should be remarked that this drive is placed on the inside that is to say, behind the wheel, looking from the outside.

Finally, the above-mentioned application on the Paris-Lyons-Mediterranean Railway relates to the drive of two of the four driving axles of the test engine 242.AE.1 supplied to the Paris-Lyons-Mediterranean Company by the Société

Alsacienne de Constructions Mécaniques, of Belfort (now the Société Als.-Thom.). This drive, which is very similar to that mentioned above, but which is outside the axle, is described in the January 1927 *Bulletin* of the said Société.

A third modification of the quill drive is that of the A E G (Allgemeine Elektrizitäts-Gesellschaft, Berlin), and which so far has been used on 40 express electric locomotives of the German State Railway Company (Deutsche Reichsbahn Gesellschaft). This drive differs from the original quill drive and the Sécheron modification in that all the springs are now subjected to *compression alone*, a considerable advantage, since in the two other drives aforementioned the springs are subjected, in addition to compression, to tension, torsion and bending. As may be seen in figure 9, there are in this case also six points of attachment to the hollow shaft, which correspond to the driving points in figure 5 (left hand side). These points of attachment support by means of an arm a small bearing ring in two parts, the said bearing retaining on both sides two sleeves enclosing between them a single spring for each of the driving points, that is to say six springs in all for each wheel. A rim flanged at the opening limits their outward play, but their inward play on the contrary is free, which allows of the compression of the spring as soon as a tangential force acts from the gear wheel (or inversely, from a spoke of the driving wheel). In addition the spring is entirely free, while being enclosed, and is thus subjected to the minimum of wear and is protected from dust and damp. It cannot be questioned that this drive constitutes some improvement on the others, although it is of necessity a little more complicated, especially as regards the number of parts. It is very simple to take down, since it is merely necessary to take away the upper part of the small bearing rings holding the two sleeves which enclose a spring. Experience has shown that the wear caused by the friction of the sleeves (the bottom forming a sort of buffer) against the small hardened plates bolted to the bearing surfaces on the spokes of the driving wheel is a minimum, all the more so since these parts may be made of very hard metal.

Of the 40 locomotives of the German State Railways, equipped with this drive, the first two were built according to the 2-D_0-1 type (the lack of symmetry was due to the transformer); these are the two engines of the 21 series (Nos. 21.01 and 21.02), one of which has been in service for nearly four years, and the second for more than one year; the following 38 engines, series 17 (Nos. 17.101 and the following), symmetrical, 1$D_0$1 type, equally for 20 tons load per driving axle, have been put into service in succession during the last two years. These engines have been built by the A E G as regards both the electrical and the mechanical equipment and this modified axle drive bears the name of that firm. The Siemens-Schuckert Works collaborated as regards the electrical equipment. As regards the experiments made with this individual axle drive, the Railway Company has expressed the opinion that up to the present the results have been very favourable, but that it is not yet possible to make a definite statement. The axle drive of these locomotives is likewise effected by means of a single gear wheel per axle (secured to one of the ends of the hollow shaft) with which gear wheel the two pinions of the twin motors mesh (fig. 9).

Fig. 9. — Axle with twin motor set, fitted with A E G drive.

Figure 10 shows an express locomotive of the series 17 of the German State Railways; an interesting application may be seen on the one hand of the *Isothermos* system of boxes to the driving axles, and on the other, the use of a forked radius rod on the outer driving axles, which connects the displacements of the carrying axle with the driving axle, thus improving the running qualities on curves. This device is derived from the Krauss-Helmholtz system of guided carrying axle acting on the first driving axle.

It may be of interest to mention at this point that the 10 locomotives of the $2\text{-}C_01+1\text{-}C_02$ type (one of which is of the double engine $2\times2C_02$ type) for a maximum speed of 105 km. (65.2 miles) or 90 km. (56 miles) per hour, equipped in 1920-1922 by the Westinghouse Company with the original quill drive and supplied to the Chicago, Milwaukee, St-Paul and Pacific Railway, have recently been converted and provided with the A E G axle drive.

As advantages and disadvantages which are peculiar to the Westinghouse quill drive or its derivatives, it may be stated in addition, that even though the ability of the driving axle to move transversely or radially while running (for example, as in the combination mentioned above) is very limited, this system still possesses considerable advantages as compared with others.

The Westinghouse drive has no linked joints and no friction contacts; the parts of which it is composed are very simple and all of them are very easily replaced; lubrication is extremely simple and the oil consumption is very low. In view of the great elasticity of the transmission of the torque between the motors and the axle, solid pinions may be provided, thus avoiding the complication of springs between the hub and the toothed rim of the pinion. A wide range of gear reduction is possible, which enables this type of engine to be used for all services. A very great advantage of this drive is the possibility of dismounting a complete driving axle very simply from below (with its motor or twin motors), without the necessity of removing the roof of the locomotive and partially dismounting the body; it is true that special plant is required to drop the axles, but all modern depots possess such plant. A very great advantage, as has been mentioned already, lies in the fact that this axle drive only gives rise to a minimum of slipping when starting up under difficult conditions.

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The next system of individual axle drive to be discussed will be the first system of the Ateliers de Construction

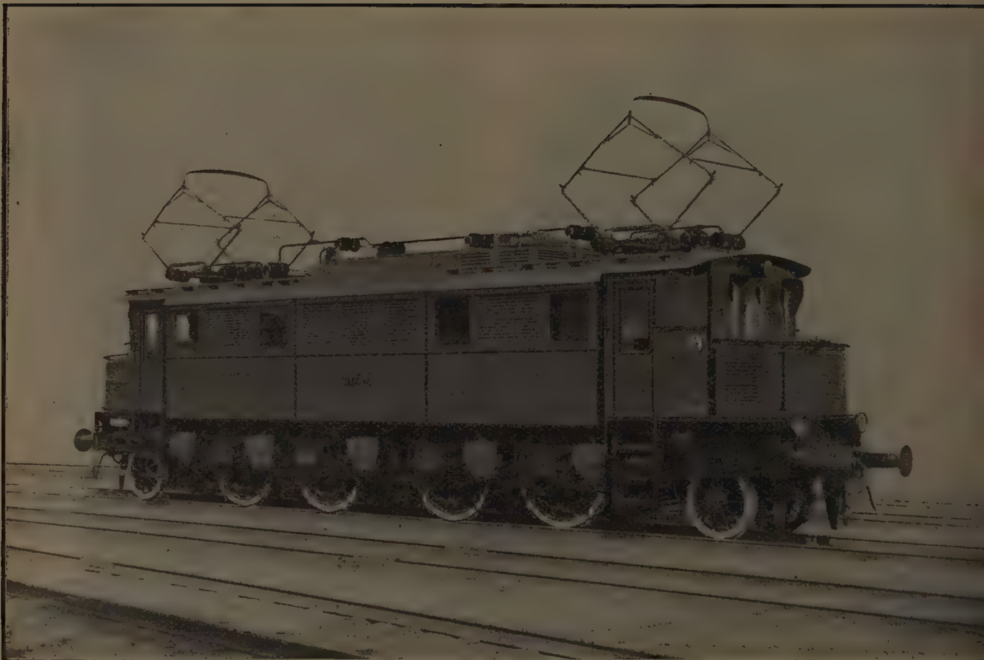


Fig. 10. — Express locomotive of the series E. 17, No. 113, type $1—D_0—1$, of the German State Railways, with A E G axle drive. A E G pho

Oerlikon in Switzerland. This is the drive which was employed in 1924 on a test locomotive of the type $2\text{-}B_0+B_0\text{-}2$, No. 242 BE I, with twin motors, 2 400 H.P., speed 110 km. (68.3 miles) per hour, of the Paris-Lyons-Mediterranean Railway Company (D. C., 1 500 volts, current collection by third rail), and previously, to a three-phase motor vehicle on the Berthoud-Thoune Line, in Switzerland, standard gauge. Recently, in 1929, the Paris-Lyons-Mediterranean put into service four $2\text{-}C_0+C_0\text{-}2$ super-locomotives, series 262 AE I, 5 400 H.P. hourly rating, equipped with this system of axle drive like the test engine; these locomotives which it is interesting to mention here because they are at present the most powerful units in the world, were supplied by the Oerlikon Company (electrical part) and the Société de Construction de Locomotives (Batignolles-Châtillon) of Nantes, as regards the mechanical part.

A brief description of this drive will be given in what follows. The drive (fig. 11) necessitates a hollow shaft and is used with outside frames. On the wheel itself are fixed, on the outside, two pivot pins placed on either side of

the axle and at an equal distance on the same diameter. These two pins are connected by rods having internal springs, to one end of two levers also arranged symmetrically relatively to the axle. These levers are connected at their centres, through openings in the discs of the driving wheels, to the hollow shaft which

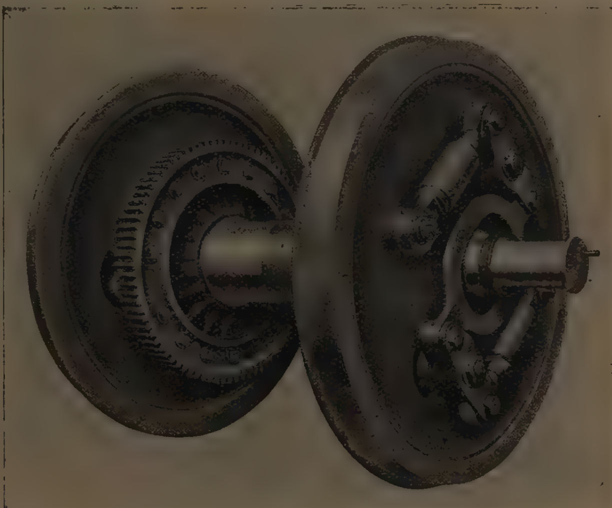


Fig. 11. — Driving axle with Oerlikon drive
(express superlocomotives of the Paris-Lycns-Mediterranean Railway).

carries the main gear wheel. The other ends of the two levers are connected together by a rigid rod opened out in the shape of an O in the centre allowing the axle journal to pass through, and embracing it. Here again a single gear wheel per axle with which mess the pinions of the two armatures of the twin motor, drives the hollow shaft on which it is secured. On the other hand, the driving couple is transmitted from both ends of the hollow shaft to the wheels of the axle (see fig. 11).

On the Paris-Lyons-Mediterranean, this system appears to have afforded complete satisfaction to the Company, since they are using it on their most up-to-date and most powerful locomotives; still, it would appear to be risky to make any definite statement yet as regards the practical value of this drive, in view of the fact that the experiments made so far are not very extensive; it is certain, however, that this method of axle drive has not given any trouble during the past years, and that it represents one of the interesting systems in present use. It possesses the advantage of being very simple in construction, and not very expensive in upkeep; the transmission rods, in particular, allowing a considerable extension in virtue of their springs (which have an

initial load of 3 000 kgr. (6600 lb.), transmission of the effort is elastic without it being necessary to provide pinions with spring-supported rims. In various respects, as regards its practical value in running, this drive compares with the Westinghouse drive which has already been described. The other, more recent, Oerlikon system of individual axle drive will be discussed in connection with the isolated constructions.

* * *

In order of seniority of application, we now come to speak of the *Skoda* axle drive, patented and constructed by the *Skoda* Works at *Plzen* in Czechoslovakia. This drive has been in use since 1926 on a series of five express locomotives, series E. 466, type 1A-AA-A1, 1 600 H.P., speed 90 km. (56 miles) per hour, of the State Railways of the Czechoslovakian Republic, already mentioned. The Skoda axle drive is shown in figures 12 and 13; it also presents much resemblance with the system of the Ganz Works, mentioned at the outset (fig. 1). Two levers A B and A' B' are fixed at A and A' in the body of the driving wheel, and can turn freely about these two points, their movement being limited, however, by the driving frame as a whole; these two levers are connected together at their other ends B B' by a rigid rod, the distance between the two points B B' being exactly the same as that between the points A A'. The four points A B B' A' thus form a regular parellogram with variable angles. Two rods C D and C' D' are attached to the two levers A B and A' B' at C and C', the heads D and D' of which rods turn about pivots fixed to the body of the main gear wheel; the arrangement is very clearly shown in the two figures mentioned above. The motion of this drive is effected as follows (fig. 12) :

When the gear wheel is moved in the clockwise direction for example, the rod D C is pulled and tends to turn the lever A B to the left about the point A, whereas a thrust is exerted on the rod C' D'; this thrust tends to make the lever A' B' rotate downwards to the right about the point A'. These movements are prevented, however, by the compensation rod B B'; the points B and B' then become the points of rotation. The lever A B turns upward to the left about B, and the lever A' B' turns downward to the right, about the point B'; these two combined movements drive the wheel and consequently the axle in a clockwise direction. In the opposite direction, the motion is effected in the same manner, except that in this case the compensation rod B B', instead of being subjected to a pull, is subjected to a thrust. The angular speeds about the pivots D and D' and those of the levers about the points A and A' are absolutely the same, that is to say, no acceleration, either positive or negative, of the driving wheel relatively to the gear wheel can be produced, and these two members run in perfect synchronism, which avoids the production of destructive efforts in the entire device. The shocks transmitted to the driving wheel by the inequalities in the track are transmitted to the parallelogram A B B' A' with the pivot pins C C' as points of rotation, without affecting the synchronism of the rotary motion of the two wheels; this synchronism is likewise preserved when, owing to shocks from the track or in curves, the axis of the axle loses momentarily its parallel position to the hollow shaft; finally, the synchronism is naturally maintained when the distance between the wheel and the gear wheel varies slightly, which is

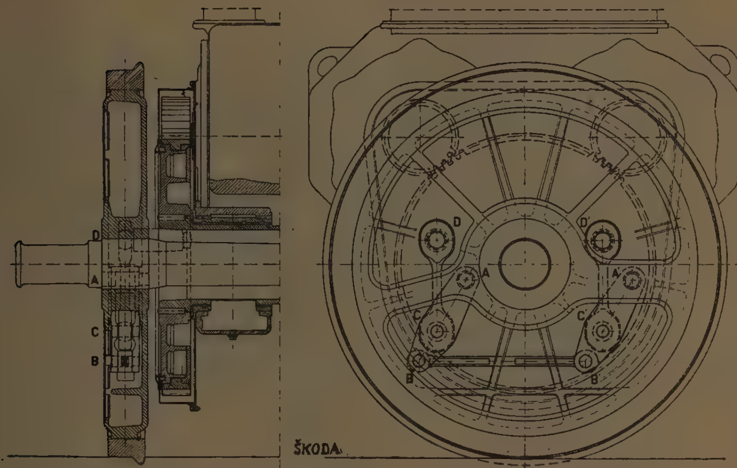


Fig. 12. — Section and elevation of an axle with twin motors, Skoda drive, of the Czechoslovakian express locomotives.

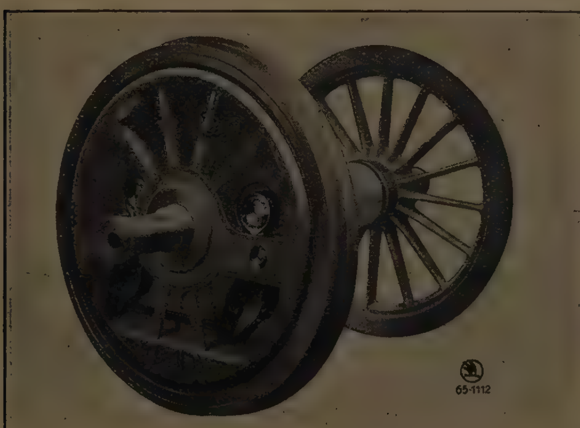


Fig. 13. — Driving axle showing the mechanism of the Skoda drive.

rendered possible by spherical bearings at D and C and enables moreover, a driving axle to be combined with a carrying axle in a bogie.

The mechanism of the Skoda coupling may be used either on one side only of the axle with the possibility of alternating the driving side (this is the construc-

tion which has been selected for the Czechoslovakian Railways), or on both sides, in which case there are two gear wheels, one on either end of the hollow shaft. The driving motors may be either single or twin for the same driving axle. Figure 14 shows the hollow shaft with the gear wheel with a rim which is elastic owing to four spiral springs; in this figure will be seen also, at the level of the gear wheel, the hole intended for securing the pivot D'. On these Skoda locomotives, the Nos. 1 and 4 driving axles are combined respectively with the carrying axle in a completely independent bogie, *comprising in its frame the twin motors complete with their axle driving mechanism;* the centre of rotation of the bogie is situated between its two axles, close to the driving axle.

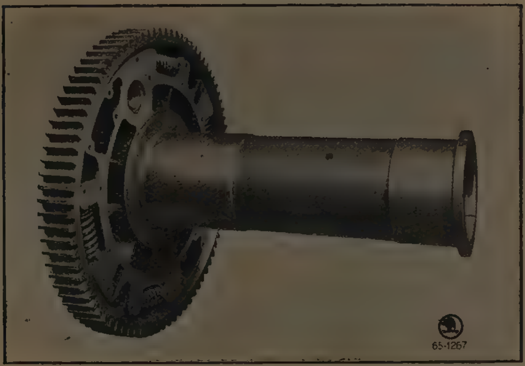
The Skoda axle drive has the advantage of being extremely simple, both from the point of view of its construction and its parts, and from the point of view of assembling; the transmission members are very accessible, all that is necessary for this is to take off the protecting plate bolted to the wheel; this cover has been removed from the axle shown in figure 13. The lubrication of the parts is fairly simple and the oil consumption is low. Finally, the method of closing the opening intended for the passage of the pivot-pins D and D' in the body of the driving wheel is simple, there being no eccentricity and no other relative movements than the shocks caused by the track (compare with what was said regarding the North of Spain drive on page 1615). As will be seen in figure 13, the side of the wheel opposite to the drive is entirely free; as is also the case for the Brown-Boveri drive, and in figure 12 will be seen the twin motors supported on the hollow shaft by the bearings in which the shaft rotates. In this respect, the arrangement is similar to the previously described Oerlikon drive, and affords moreover the same advantage as the Westinghouse drive, enabling a complete axle with its motor or motors to be dropped down, without having to remove any part of the locomotive body.

The first three of these locomotives having been in service only since 1927, it is not yet possible to pass any definite opinion on this drive, which has given very good results, however, up to the present; so far, these three engines have run a total of 100 000 and 200 000 km. (62 100 and 124 200 miles) in service. At present they are only used on the Prague suburban lines (electrified sections of the main lines which terminate in the Capital).

* * *

The « Universal » drive of the Swiss Locomotive Works, of Winterthur, will now be considered.

This drive was applied for the first time to an axle of the test locomotive No. 4 000, type 1A-AA2, of the Great Indian Peninsula Railway, already mentioned. It is even the only application which is still in service and only since 1928; nevertheless, it has resulted in an order for 21 similar locomotives (Nos. 4 004 to 4 024, series EA/1), now being constructed. The Administration of the Indian State Railways has given the preference to this system, in competition with three others, applied on three different test locomotives (See pages 1613 (*d*) and 1637). These locomotives are intended for the lines from Bombay to Poona and to Igatpuri, operated with D. C. at 1 400 volts by overhead conductors; gauge 1.676 m. (5 ft. 6 in.); maximum speed 120/137 km. (75/85 miles) per hour,



Skoda block.

Fig. 14. — Hollow shaft with elastic gear wheel of the Skoda drive.

maximum load per axle 21 tons. The hourly power of a locomotive is about 2 200 H.P., and at the hourly rating, the tractive effort developed is nearly 10 000 kgr. (22 000 lb.) at 37 km. (23 miles) per hour (clear track). The electrical part of these engines was supplied by the Metropolitan-Vickers Company of Manchester; the mechanical part by the above mentioned works at Winterthur. The single carrying axle at the front of the engine is combined with the adjacent driving axle in a Java type of bogie, which also has been mentioned already (see page 1616) (1).

A similar locomotive, but of the type $2\text{-}C_0+C_0\text{-}2$, for 110 km. (68.3 miles) per hour, intended for trial working on the Irun-Alsasua line of the previously mentioned North of Spain Railways is at present being built at the Reinosa Works of the « Sociedad Española de Construccion Naval ». The electrical equipment of this engine has also been supplied by Metropolitan-Vickers, and the axle drive by Winterthur.

Lastly, it is of interest to mention at this point that the Swiss Federal Railways have just placed an order for two test electric superlocomotives, intended for all services on the Gothard (Lucerne-Chiasso) line. One of these engines will be provided with the axle drive which has been standardised on the Swiss Federal Railways, the Brown-Boveri system on one side only, described at the commencement of this chapter, while the second is to be equipped with the Winterthur « universal drive ». These two engines will be of the type 1A-A1A-A1+1A-A1A-A1, that is, having 14 axles, of which 8 driving axles will develop at the hourly rating a power of nearly 7 000 H.P., and will thus be by far the most powerful electric locomotives in the world. Each semi-locomotive will be provided at its

(1) For the description of these locomotives, see the December-January number for 1929-1930 of the review *La Traction Électrique*, Paris.

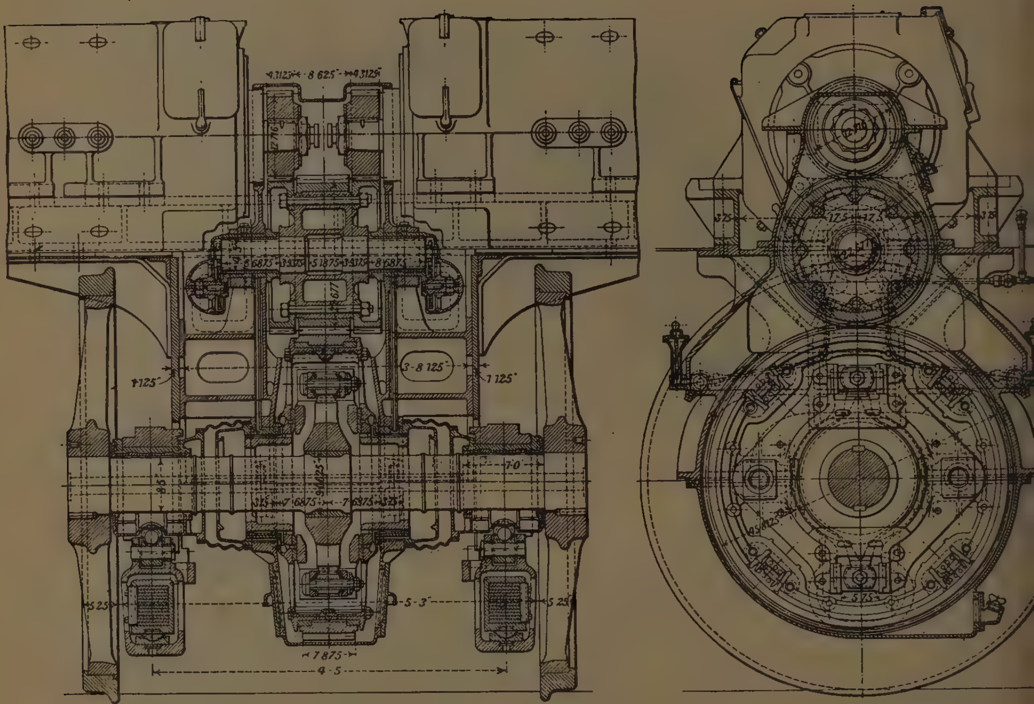


Fig. 15. — « Universal » coupling of the Swiss Locomotive Works at Winterthur, Great Indian Peninsula Railway construction.

ends with two bogies composed of the carrying axle and the adjacent driving axle; adhesive weight 160 tons, length over buffers 32 m. (105 feet) and speed 100 km. (62 miles) per hour.

The Winterthur individual axle drive may be described as follows (fig. 15 and 16) :

In the middle of the shaft of the driving axle there is secured diametrically to the said shaft an arm (vertical in the two figures mentioned), terminating in two spherical heads, embraced by and held in two rectangular sliding bearings, very clearly to be seen in the figures. The transmission between the heads of the diametric arm and the body of the main gear wheel is effected by means of a rigid parallelogram, also to be seen in the figures referred to. On the right and left of the horizontal diameter of this parallelogram (which diameter would become vertical if the wheel were turned through 90°) are located two other slides, which are capable of sliding in slots parallel to the horizontal diameter

Winterthur block.

Fig. 16. — Winterthur « Universal » drive;
arrangement of the coupling inside the large gear wheel.

in the position shown in the figures. It will be seen that this mechanism enables at any moment the most varied displacements of the axle (particularly, vertical displacements, and displacements about a point of rotation of the driving axle of a Java bogie) relatively to the body of the main gear wheel.

The body of this main gear wheel is secured rigidly to the hollow shaft, surrounding the axle shaft. This hollow shaft rotates in two bearings, the upper portion of which is fixed to the main frame of the locomotive and is integral with the bearings of the other gear wheels. In other words, the main gear wheel follows exactly the movements of the main frame of the locomotive; all the displacements made by the axles relatively to this frame are compensated for by the parallelogram mechanism previously mentioned. With the object of imparting to the transmission of the traction effort itself the desired flexibility, the rim of the main gear wheel is connected to the body by means of four small spiral springs, clearly shown in figure 16.

Above the gear wheel are located, on the same intermediate shaft, three intermediate gear wheels placed side by side, the diameter and gearing of which are the same or different according to the reduction ratio; the middle one of these gear wheels is engaged from below by the main gear wheel, and the two outer gear wheels, with helical gearing in different

Fig. 17. — Dismounting the traction motors of the « Winterthur » drive
(Great Indian Peninsula Railway trial locomotive).

directions, mesh in their turn with the pinions of the two traction motors driving an axle. The object of this arrangement is to cause each gear wheel to mesh in one point only, that is to say, on a single generatrix of its periphery, which considerably increases the life of the gearing. The two motors of an axle are thus situated on either side of the two pinions and their armatures are in the same axis; the motors may be dismounted from the locomotive very easily by drawing them towards the outside, after opening panels provided for this purpose in the sides of the locomotive. Figure 17 shows the very simple manner in which the motors are removed; it will be seen also that this drive leaves the axles entirely free towards the outside.

This type of axle drive mechanism in which the driving couple is transmitted to the axle shaft in its centre, a feature which is also found in some other drives to be described later (in this connection, see the Linke-Hofmann drive, page 1639, and the drives with vertical motors and bevel gears, pages 1639 and the following), exhibits by virtue of this fact, fundamental differences with respect to the other systems, which have already been described or are yet to be described. In fact, hitherto, the driving effort has always been transmitted to pivot pins secured to the spokes or disc of the driving wheels, thus acting directly if not on the periphery itself of the wheel, at least tangentially to a circle of a certain diameter (lever), thus avoiding transmission

by the shaft of the axle itself, except in those cases in which the drive is effected on one side only. In this case, however, the driving couple is transmitted from the driving side to the wheel on the opposite side, thus passing through the entire length of the axle shaft. It is clear that the torsion of the shaft, taken over the *whole of its length*, helps to give a certain elasticity to the transmission. In the case under consideration at the moment, however, the driving effort is transmitted solely to arms situated in the *middle of the axle shaft*, and thence (through the agency of the half lengths of this shaft on either side, and through the lever arm formed by the wheel spokes) to the rim of the driving wheels. There can be no doubt whatever that, mechanically, especially when it is a question of the transmission of a considerable effort, this drive results in a greater fatigue, both of the axle shaft itself and more particularly of the spokes of the driving wheels; for this reason, therefore, it will probably be necessary to provide more robust dimensions for these parts. Future experience will show the extent to which these influences will make themselves felt practically.

In connection with this general remark, the following may be said regarding the relative advantages and disadvantages peculiar to this system :

Owing to a satisfactory enclosing and arrangement of the bearings of the main and auxiliary gears, the transmission system is entirely enclosed, ensuring a minimum consumption of oil with very good lubrication, and prevents dust finding its way in. The drive is simple in its parts, which are in consequence easy to replace; they may be replaced from below, without it being necessary to dismount an axle. The accessibility of the drive mechanism is thus quite good, although inspections have to be made from below, between the wheels, the engine having to be placed on an inspection pit. As was mentioned previously, each gear wheel only possesses one point of engagement, which partly compensates for the double gear transmission; on the other hand, this double transmission enables different gear ratios and driving wheels of very different diameters to be used, and consequently, the use of the system for very wide ranges of speed. In addition, the double gear reduction enables high speed motors to be used, and therefore, motors which are small and light per unit of power, and also results in very slight losses which may only be 1/2 % of the total power.

This axle drive is used indifferently and in exactly the same way either for locomotives with outside frames or for locomotives with inside frames; this is, in particular, an advantage for the constructor, because some railways prefer inside frames and others outside frames Lastly, the mechanism is symmetrically arranged and the centre of gravity of the motors is high up, which as is known, helps to increase the satisfactory running qualities at speed.

Another factor which may act in the same direction is that of the influence of the gyratory movement of the rotating masses. Owing to the double gear reduction, the armatures of the motors always rotate in the same direction as the axles and it is possible that this factor also influences the satisfactory running qualities, especially when running through curves, all the more so since, the motors being placed on the outer edges of the two sides of the locomotives, the influence on transverse oscillations is likewise satisfactory.

It would be difficult to determine exactly, by calculation, the influence of these factors, but it is certain that the practical trials which will have been made with this drive (as soon as a certain number of locomotives of this type have been running for some years) will show better the respective qualities or disadvantages of the different systems. There is no doubt that the Winterthur drive also offers very interesting possibilities for the future.

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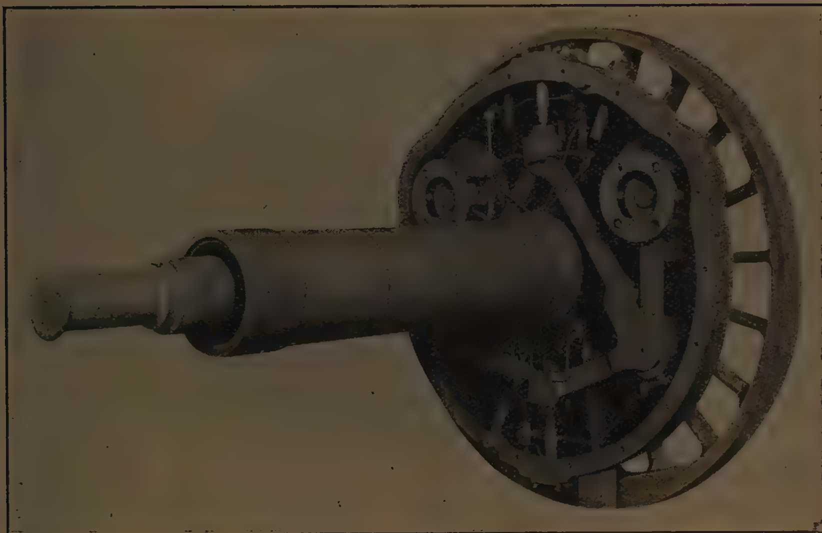
To conclude the description of the drives with motors having their shaft horizontal and parallel to the axle, the five constructions following will be mentioned, each applied in one or two isolated cases only, and arranged below in order of seniority :

1. The « Forges et Ateliers de Constructions Electriques de Jeumont » system of coupling (a system which is mentioned here for the purpose of refreshing the memory and for the sake of completeness), was used, nearly twenty years ago, on a test locomotive, $1\text{-}C_0\text{-}1$, No. E 3401, of the Compagnie des Chemins de fer du Midi (French Midi Railway Company) at the beginning of electrification with single-phase current. As far as the writer is aware, this system is no longer in use and has not been used elsewhere, but it is interesting from the historical point of view. The hollow shaft surrounding the axle is provided at its end with two arms placed on the same diameter, and supporting, by means of slides, a collar concentric with the axle. This collar is also secured, at the ends of a diameter perpendicular to that first mentioned and by means of small interposed spiral springs, to the driving wheel which has a fully dished centre, like that shown further on in figures 21 and 22. A description of this system was given in the German periodical *Elektrische Kraftbetriebe und Bahnen*, 1912, page 546; there is no doubt a description in the French technical literature also.

2. Next comes the « Tschanz » individual axle drive, so called from the name of its inventor, O. Tschanz, one time Chief Rolling Stock and Traction Engineer of the Swiss Federal Railways. This system may be described as follows : In the original construction as applied on one axle only of a small test engine No. 11001 of the Swiss Federal Railways, the driving axle itself is tubular. An auxiliary shaft, connected by universal couplings to the driving wheel itself and to the rim of a gear wheel, passes through the hollow axle. The gear wheel, rotating in a bearing, external and rigid relatively to the main engine frame, drives on that side an intermediate shaft, which in its turn is provided, at the opposite end (that is to say, on the same side as that on which the auxiliary shaft engages the driving wheel) with a gear wheel with which the motor pinion meshes; the intermediate shaft thus passes to one side of, and external to, the traction motor. The axes of the intermediate shaft and of the armature of the motor lie in the same horizontal plane above the driving axle and on either side of its axis. In a later use, the drive was employed for two of the driving axles of the test locomotive, articulated in three parts, type $1B_01\text{-}1B_01$, No. 11000 of the Swiss Federal Railways, an engine built in 1918. The drive was modified so as to avoid the tubular axle surrounding the auxiliary shaft. A short auxiliary shaft is located outside and at one end only of the axle and in the prolongation thereof.



Engineering block.

Fig. 18. — Oerlikon individual axle drive as applied to the test locomotive No. 4001 of the Great Indian Peninsula Railway.

This short shaft is connected at both ends by universal joints to the driving wheel, which it drives, and to a gear wheel by which it is driven. This gear wheel is actuated in its turn by an intermediate shaft, the opposite end of which meshes with the pinion of the motor as in the case already described. In this case the power is nearly 700 H.P., while it was scarcely 500 H.P. in the first engine built. In addition, therefore, to the complication of either the tubular axle or the prolongation (suspended on the outside) of this axle, the Tschanz drive requires a double gear as well as the provision of an intermediate shaft. Apart from these disadvantages, this system possesses on the other hand the advantage of great flexibility and suppleness and the possibility of obtaining any desired gear ratio. The other two driving axles of the test engine 11000, and also at the beginning, the second axle of the engine 11001, have been fitted with the Brown-Boveri individual drive, which has been used there as a test for subsequent applications (see page 1612).

3. Now comes the second system of individual axle drive of the Ateliers de Construction Oerlikon. This drive is shown in figure 18 and has been used once only, on the test locomotive No. 4001, type 2-C_0-2, of the Great Indian Peninsula Railway (see page 1630), gauge 1.676 m. (5 ft. 6 in.), speed 120/135 km.(75/85 miles) per hour, other features similar; electrical equipment by the General Electric Company of London; mechanical part supplied by R. & W. Hawthorn, Leslie

& Co. Ltd., of Newcastle-on-Tyne. This system may be described as follows :

The pinions of the two twin traction motors which drive one driving axle mesh with the toothed rim transmitting the torque; this transmission is rendered elastic by means of six sets of convergent multiple leaf springs, in the form of biconvex lenses, fixed between the hub and the toothed rim. The toothed wheel is fixed to a casing of the same dimensions, integral with the hollow shaft and containing the drive proper. The gear wheel consequently drives this casing which comprises on its vertical diameter (in the figure) and nearly against the wheel, two guides in which guide blocks slide. These guide blocks enclose and support the joints which may be seen in the figure at the top and bottom of the quadrilateral frame of rods surrounding the hollow shaft. Finally, two rods, directed upwardly, are secured by spherical bearings to the lateral angles of this frame and these rods by their opposite ends drive the two pivot pins secured to the driving wheel. It is these two pivot pins which in turn drive the driving wheel.

The hollow shaft turns in bearings fixed to the bottom of the frame of the twin motor, thus ensuring perfect engagement of the gears. The coupling frame is made in two parts to facilitate dismounting; the axis of symmetry of the mechanism is the axis in a vertical position on the figure. This drive mechanism possesses no more than six joints properly so called in all, two of which are sliding joints, and it is perfectly balanced from the point of view of the rotating masses. The complete mechanism (as well as the gears on the opposite side) is entirely enclosed, which is very favourable for satisfactory lubrication and a minimum consumption of oil. Lubrication is very complicated, however. This system also leaves the driving wheels entirely free on the outside. Considering the small amount of space which this drive leaves available for the motors, the writer believes that it can hardly be used except for engines of wider gauge than the normal gauge. In addition, it requires a large driving wheel diameter, as well as the external frame, which further restricts its sphere of application.

4. Fourthly, we come to the articulated coupling of the Société Générale de Constructions Electriques et Mécaniques Als-Thom, formerly Société Alsacienne de Constructions Mécaniques, Belfort; this coupling is shown in figure 19 and was used on two driving axles of the test locomotive $2\text{-}B_0 + B_0\text{-}2$, No. 242, AE. I. of the Paris-Lyons-Mediterranean, the other two driving axles of this locomotive being equipped with a drive similar to the quill drive (see page 1623).

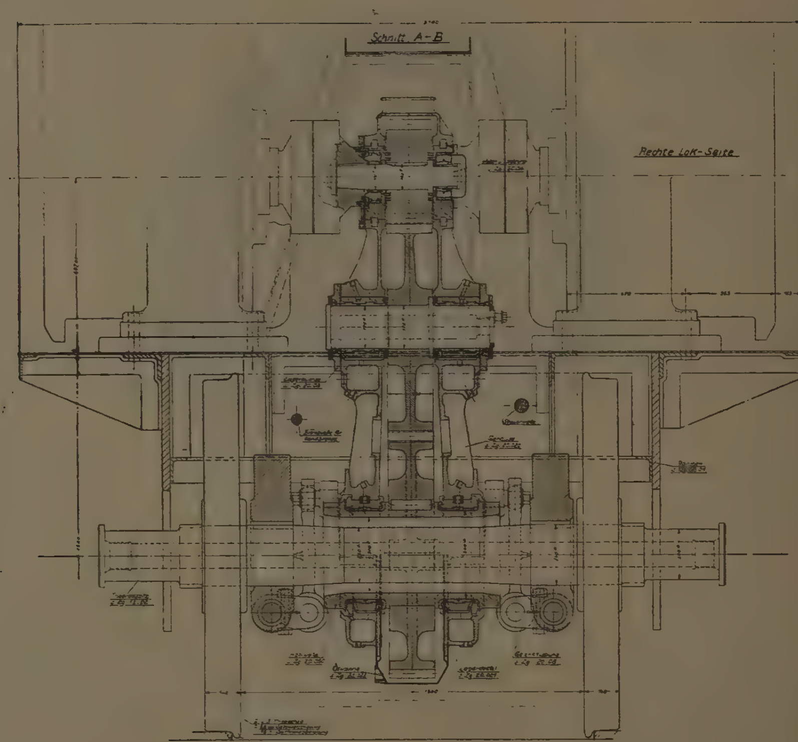
This system, similar in many respects to others, is provided, as for example for the first Oerlikon drive (likewise used on the P. L. M. and described on pages 1626/7, fig. 11), with two pivot pins fixed to the driving wheel and two pivot pins fixed to the gear wheel, and which pass through openings in the driving wheel. The pivot pins fixed to the driving wheel are connected to the pivot pins fixed to the gear wheel by two pairs of levers forming a right angle between them in the normal position and which are connected by linked joints. These two linked joints are connected together by a sort of rigid coupling rod, which is provided with an opening in its middle portion surrounding the axle journal. For a more detailed description, the reader is referred to the January *Bulletin* of the above-mentioned Société Alsacienne. It is certain that this drive is very simple and very accessible

Als-Thom block.

Fig. 19. — The « Société Alsacienne » axle drive used on No. 242 locomotive, AE. I of the Paris-Lyons-Mediterranean Railway.

as regards inspections. The parts of which it is composed are very simple.

5. The Linke-Hofmann will be mentioned to complete this series. This system has recently been fitted on four driving axles of the locomotive No. 21.51 of the German State Railway Company, in Germany. This engine, the electrical equipment of which was supplied by the Bergmann Works, comes from the Linke-Hofmann-Busch works, at Breslau, the constructors of this drive which is shown in figure 20. It will be seen at once that this mechanism, especially in its general arrangement, exhibits a close resemblance to the Winterthur universal drive (fig. 15). It differs from the latter, in the first place, by the fact that the two traction motors drive the same pinion through the agency of elastic couplings, the pinion, by an intermediate gear wheel, driving the main gear wheel secured to a hollow shaft surrounding the axle shaft. The entire part constituted by the bearings of these three gear wheels is here again rigid relatively to the main frame of the locomotive. The transmission of the hollow shaft to the driving axle takes place by a mechanism very similar (but applied on either side of the gear wheel) to that employed by the Siemens-Schuckert works for the locomotives series 1570 and 1670 with vertical motors and bevel gears of the Austrian State Railways (see figure 24), a description of which mechanism is given later under the systems of drive with vertical motor. For a more detailed description of the Linke-Hofmann drive, the reader is referred to the June 1926 number pages 209 to 213, of the periodical *Elektrische Bahnen*, Berlin. This drive is too recent (barely one year in its *present* design) to be able to form an opinion regarding it.



LHB block.

Fig. 20. — Mechanism of the Linke-Hofmann axle drive, applied to the locomotive series 21, No. 51 of the German State Railways.

CLASS D.

Individual axle drives with motors having a vertical axis and bevel gearing.

There are two known systems of drive of this type used on a certain number of locomotives.

In the first place, the system used by the Société des Constructions de France, Tarbes Works, on the express locomotives type 2-C_0-2 of the Compagnie des Chemins de fer du Midi (French Midi Railway Company). Two first locomotives of this type, Nos. E. 3101 and E. 3102 were put into service in 1923. Since that time, eight other engines of the same type have been put into service successively. The latter develop 2 100 H. P. at the hourly rating and a speed of up to 125/130 km. (77.7/80.8 miles) per hour and are equipped with the same system of drive, but modified and improved. The more recent series will be described first and then the two types of mechanism will be compared.

Each driving axle is driven by two twin motors having their armature vertical, the axis of the two armatures being in the same plane as the axis of the corresponding axle. No description of these locomotives will be given here; they have been the subject of an extremely well informed article by Mr. Bachellery, Chief Engineer of Rolling Stock and Traction of the French Midi Railway Company, in the May 1928 number of the *Revue Générale des Chemins de Fer*, pages 357 to 374. The writer will confine himself to repeating below the description given of the transmission (see figures 21 and 22 and also the comparative description on pages 1641/1643):

The motion of the motors is transmitted to the axles by means of hollow shafts on which are keyed the gear wheels. There corresponds, to each axle, one of these shafts, 320 mm. (12 9/16 in.) in external diameter, which surrounds the axle, leaving a circular gap of 40 mm. (1 9/16 inches) and which is supported in two bearings fixed to the corresponding motors. The motion of the hollow shaft is transmitted to the driving wheels through a universal elastic joint. This joint consists essentially of a crown carrying four lugs, two of which are connected to a plate fixed on the hollow shaft and the other two to the body of the wheel through helical springs working in compression. This crown, being entirely free, allows the axle to move in all directions relatively to the hollow shaft under the action of the inequalities of the track, without the springs being subjected to any abnormal fatigue. The motors are thus made independent of the shocks produced between the trains of wheels and the rails. As regards the shocks which tend to be produced in the gearing on the occasion of sudden variations in the driving couple, for example, on starting on when slipping takes place, they are also absorbed by the elastic transmission. As was explained previously, the drive by twin motors rotating in opposite directions has the effect of balancing the longitudinal reactions on the hollow shaft, so that there is no need to provide this shaft with thrust bearings.

It may be added that the reduction ratio of the gear of these locomotives is 1 : 3.5; the bevel gears have rectilinear involute teeth.

The difference between the first system of transmission (express locomotives E. 3101 and E. 3102 of the Midi, fig. 22) and the improved system of the series E. 3103 (fig. 21) is as follows : in the first case the four « poles » of the double ring B movable in all directions, which will be called for the sake of simplicity, the universal ring, and which serves the purpose of an intermediate member between the transmission arms G, the ends of the hollow shaft H and the points F fixed to the wheel, are each attached to two of these members by two spiral springs fixed on both sides of the same pivot J on these poles. In other words, two of the poles (at opposite ends of the same diameter) are each connected on both sides by a spiral spring to two adjacent arms of the four arms fixed to each end of the hollow shaft. Similarly, the two poles which are on the diameter of the universal ring which is perpendicular to the aforementioned diameter are each connected on either side by a spiral spring to a pair of fixed adjacent points F on the wheel; to each wheel, therefore, there corresponds eight spiral springs, two pairs of fixed points F on the wheel (symmetrical relatively to one and the same diameter) and two pairs of arms G at each end of the hollow shaft (symmetrical relatively to a diameter perpendicular to the preceding diameter). All these eight springs, sixteen per axle, are free, that is

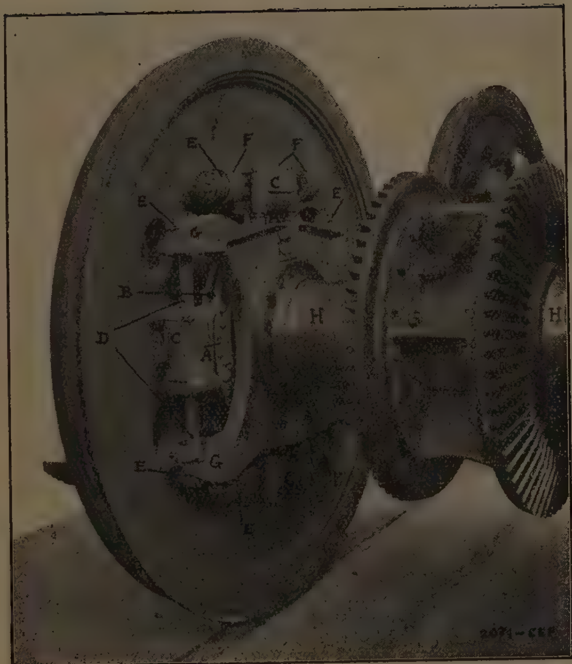
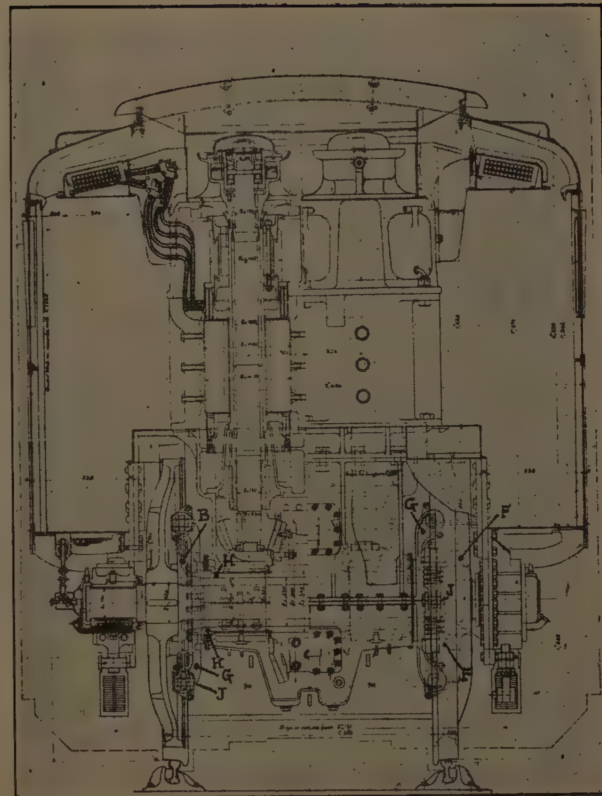


Fig. 21.

Driving axle with drive mechanism and bevel gear wheels of the locomotives series E. 3103 of the French Midi Railway.



From CFF drawing.

Fig. 22.

Vertical section through a driving axle of the express locomotives E. 3101 and E. 3102 of the French Midi Railway.

to say, they are not enclosed (see figure 22, the right hand wheel). The attachment of the springs to the poles of the universal ring by the pivot pins J is similar to that adopted for the pivot pins N of the hollow shaft of the device shown in figure 8 (rail motor vehicles of the French State Railways) except for this difference that in the case at present under consideration the two springs of one and the same pair are in the same axis, that is to say, in the extension of one another [1].

In the improved system (fig. 21) there are, on the contrary, sixteen springs per wheel, i. e., four for each pole A of the universal movement ring B : of these four springs, two are held at the pole itself in a sleeve C which is open at both ends (this device presents a vague resemblance with that described on page 1624 of the A E G drive), and hold the two buffer rods D which effect the transmission through the agency of the springs, tightly one against the other; the other two springs E of one and the same pole are not enclosed and suspend in an elastic manner the opposite ends (secured respectively either to the pairs of fixed points F on the wheel, or to the pairs of arms G of the hollow shaft H) of the above-mentioned rods. This device will be better understood by comparing figure 21 with the right hand wheel of the axle shown in section in figure 22.

In the second place, a description of the individual axle drive of the Siemens-Schuckert Works (Austrian Company), will be given, which drive has been used on the express locomotives, series 1570 and 1670, of the Austrian State Railways previously mentioned. These two series of locomotives are both of the type $1D_01$ (1A-AA-A1) having external framing, the carrying axle being combined with the adjacent driving axle in an independent bogie also having outside frames, and of which the centre of rotation is located between the two bogie axles. Here, however, as in the case of the Brown-Boveri drive (1A-AA-A1 locomotives of the Dutch East Indies, the German State Railways, the Paulista Company, etc., described at the beginning of this article, pages 1613 and the following) the motors are fixed to the main frame of the locomotive, whereas, for instance, in the Skoda Czechoslovakian locomotives, the twin motor is suspended in the bogie frame (see p. 1630). The electrical equipment of all these engines with vertical motors of the Austrian Railways has been supplied by the Siemens-Schuckert Austrian Company, and the mechanical part by the Locomotive Works of Krauss & Co. at Linz; as regards the series 1670, there has also been collaboration with the « Wiener-Lokomotiv-Fabriks A.-G. » of Vienna.

The features of these engines are the following : series 1570 comprises four locomotives, Nos. 1570.01-04, put into service in 1925-1926, of 2 160 H. P. at the hourly rating at the tread, maximum tractive effort at starting 17 000 kgr. (37 480 lb.), maximum speed under running conditions 85 km. (52.8 miles) per hour, maximum weight per driving axle 16 tons, gear ratio 1 : 3.824. The bevel gears are helicoidal. Each of the four driving axles is driven by a single vertical axis motor, the axis of the motor being located in the plane of the corresponding driving axle; the side on which is the main gear wheel is alternated relatively to the motor, as also is the spacing of the armature axis relatively to the longitudinal axis of the locomotive. This space is 150 mm. and in consequence the space

(1) For the figure showing this first device of the Midi, see *La Technique Moderne*, number for May, 1924.

between the vertical planes of the motors 1-3 and 2-4 is 300 mm. (11 13/16 inches). The direction of rotation alternates also, which means that the side on which is the gearing alternates. Finally, the motors of the series 1570 are « suspended » as in the Midi type (fig. 22) : the armature shaft is supported in its upper portion in double collared bearings, but without ball bearings. The double collar is necessary in order to resist the upward reactions caused by the bevel gear. Unlike the Midi motors constructed in the Liége shops of the Société des Constructions Electriques de Belgique, and in which the armature shaft has only two guide bearings (immediately above and below the body of the armature), the Siemens motors of the Austrian series 1570 have, in addition to these two bearings, a third guide bearing at the lower end of the armature shaft, below the pinion : this arrangement was necessary because the axial thrust at starting may attain 105 % of the pressure exerted by the starting couple on the gearing.

As regards the series 1670, it comprises 29 locomotives, the first of which were put into service in 1928. The necessity for greater power led to the use of two twin motors per axle and advantage was taken of the experiments made with the four engines of the series 1570 to introduce various improvements into the new type. These locomotives have a power at the rim of 2 760 H.P. at the hourly rating, the maximum tractive effort at starting is 19 400 kgr. (42 770 lb.); the maximum speed is 100 km. (62 miles) per hour; the gear ratio is 1 : 3.842. The weight per driving axle is 16.2 English tons; this is the maximum permissible load for electric locomotives on this railway (BBOe). All these figures are the official figures of the Company. The locomotives of the series 1670, as already mentioned, have two twin motors per axle, the axes of the two armatures being situated in this case also in the same vertical plane as the axis of the axle. The two motors of one axle rotate in opposite directions relatively to one another. These engines, as regards their general structure (as moreover, those of the French Midi) are absolutely symmetrical relatively to their longitudinal axis and their median transversal axis. Figure 23 shows a driving axle of the series 1670 with the casing C enclosing the coupling mechanism between the hollow shaft and the axle : on the two ends of this casing are bolted the two geared rims with bevel gearing, the gearing in this case being rectilinear as on the Midi Railway. This figure also shows above the axle the support V of the two vertical motors of one axle, which support comprises in its lower portion the bearings P in which rotates the hollow shaft, with the transmission mechanism and the gear rims. This support also helps in strengthening the locomotive frame and is exceptionally robust, for it comprises in this case the support bearings (properly speaking, the bushes) of the armatures : the latter are therefore not suspended from above as in the two types which have just been described but are supported on their base. This new arrangement has the two great advantages of diminishing the danger of oil penetrating the windings of the motor and of enabling the armature shaft to be made in sections, so that in case of damage to a motor, it is possible to separate the latter mechanically from the axle.

The Siemens-Schuckert transmission mechanism may be described as follows (fig. 24) :

The two toothed bevel rims of the main gear wheels of one axle (or one rim alone

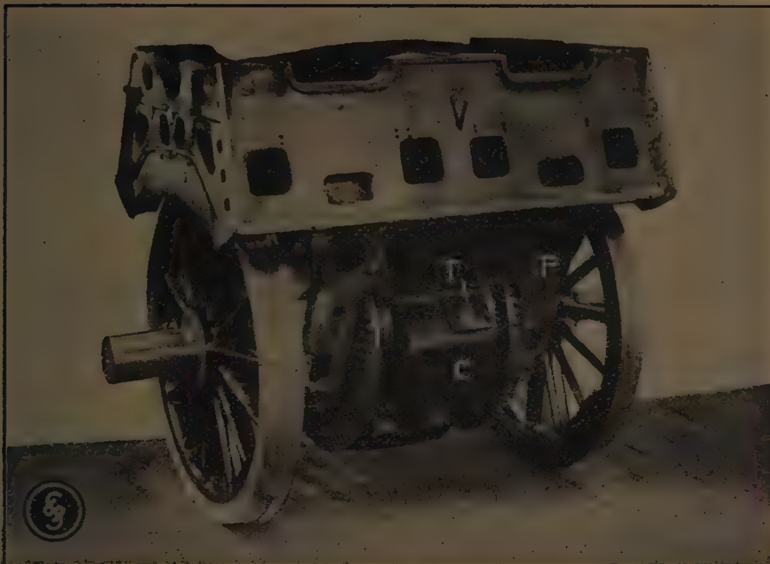
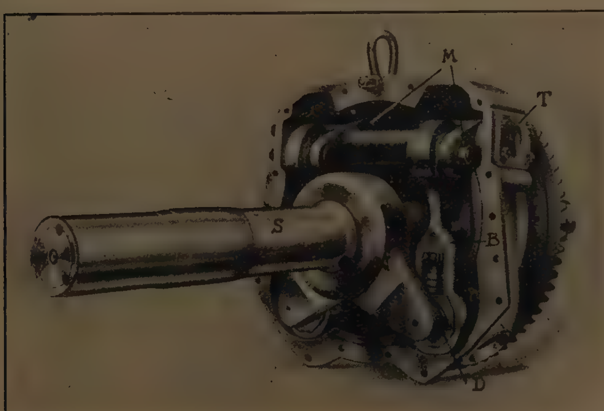


Fig. 23. — Driving axle with drive mechanism, support and gear wheels of the express locomotives, series 1670 of the Austrian Federal Railways.



SSW photo.

Fig. 24. — Siemens-Schuckert transmission for vertical motors and bevel gearing (locomotives series 1670).

for the series 1570) are secured to a casing of cast steel (C in figure 23) enclosing the transmission system, the casing being capable of being taken apart and integral with a section of hollow shaft. This hollow shaft, not shown in figures 23 and 24, and which surrounds the axle, itself rotates in the bearings P placed on both sides of the transmission and integral with the main frame of the locomotive and with the frame of the vertical twin motors (see figure 23, on each side of the casing fitted with the toothed rims). Above these bearings are located the guide bearings of the vertical shafts of the gearing (extension of the armature shafts), immediately below the bevel pinions. In the upper portion (in the position shown in figure 24) of the casing enclosing the transmission mechanism, is placed a shaft capable of turning about its journals; on this shaft (the journals T of which are visible in the two figures 23 and 24) are placed in proximity to the journals, two cranks M from which are hung two rods. These two rods B are capable of moving at their opposite end about two pivot pins D fixed to a very strong collar N having arms and keyed to S, the shaft of the axle itself. The four links forming the ends of the two rods are made in the form of spherical bearings, thus permitting considerable freedom of movement of the axle relatively to the main frame of the locomotive. In the first type (series 1570) it is the armature shaft itself which carries the pinion between the guide bearing and the shield bearing of the motor, while in the new construction with twin motors (series 1670) the shaft carrying the pinion is connected to the armature shaft by a special joint, which, as already mentioned, enables these two members to be separated easily in case of necessity.

* * *

This examination will be terminated by a few words of conclusion, general considerations on the individual drive with vertical motors and bevel gearing.

It is certain that this arrangement places the centre of gravity of the motors very high in the engine, and in consequence assists in raising the centre of gravity of the locomotive itself as high as possible. Now, it is known that a high centre of gravity improves considerably the running qualities of a locomotive: this experience is old and dates from the very commencement of high speed running with steam traction. On the other hand, the gyratory motion of the vertical motors improves, in its turn, the stability of the locomotives when running. The present writer has had the occasion to travel at speeds of 120 to 125 km. (74.6 to 77.7 miles) per hour on the 2-C_0-2 engines of the French Midi Railway, between Bordeaux and Dax, and also at speeds of 95 to 100 km. (59 to 62 miles) per hour on the engines of the series 1570 of the Austrian Railways between Innsbrück and Wörgl [although these 1570 series engines had been constructed for a maximum speed of 85 km. (52.8 miles), they were allowed to run at speeds up to 95 km. (59 miles) per hour on lines on the level, in view of the good running qualities of these engines and the satisfactory results of the tests], and finally at speeds of 90 to 95 km. (56 to 59 miles) on the engines of the series 1670 of the BB0e, between Bludenz and Buchs (Arlberg line). During all these runs, taking into consideration the state of the permanent way and the track on the sections in question, the writer was able to note the exceptionally good running qualities, and what is rarely encountered in this connection it is in particular possible on these locomotives, much better than on other types, to stand in the driver's cab

at high speeds without holding on, and even with the heels together. In this way, the stabilising action of the above-mentioned factors may be experienced.

It will be observed that there exists between these two systems, the Midi and the Austrian, the same fundamental difference which was discussed on page 1634 in connection with the Winterthur universal drive; the Midi axle drive transmits the torque directly to the hollow shaft at the plates or discs of the two wheels of an axle, while the Siemens-Austrian drive transmits all the driving effort to the centre of the shaft of an axle, whence it is transmitted in its turn to the rims by the agency of the half-lengths only of the shaft and the lever arm formed by the wheel spokes. It will be necessary, in this case also, to provide very robust wheels, possibly webbed between the spokes.

The advantage of the very great stability in running of the vertical motor locomotives has already been mentioned; the disadvantages of the principle of these systems which may be mentioned are the bevel gearing (which has not, however, given rise to very great difficulties), the complication of lubrication, the adjustement of the support and guide bearings, and finally the fact that in certain cases, these systems bring the base of the gear casings very near the track, which increases the risk of damaging the casings and so may lead to interruption of the lubrication.

As indirect advantages of the drive by vertical motors may be mentioned the possibility of using wheels of fairly small diameter (hence a reduction in the unsuspended weight, an advantage which is also to be found in other systems), and then the very good accessibility, during running, of the motors and collectors.

The writer hopes that he has given the reader a relatively complete although brief general review of a very interesting chapter of the very vast question of the axle drive of locomotives (1). He takes this opportunity of thanking the Railway Companies and the Manufacturers, mentioned in the course of the paper, who have kindly placed at his disposal documents, photographs, drawings, blocks, etc.

(1) In addition to the numerous references to the technical literature, mentioned in the course of the paper, those interested are referred to the book by Dr. K. Sachs of Baden (Switzerland) : *Elektrische Vollbahnlokomotiven*, published by Springer, Berlin, 1928.

[624 .63, 625 .142.4 & 721.9]

SUPPLEMENT No. 2 TO REPORT No. 1 [1]

(Belgium, France, Italy, Portugal, Spain and their Colonies and Switzerland)

ON THE QUESTION OF THE USE OF CONCRETE AND REINFORCED CONCRETE ON RAILWAYS (SUBJECT I FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION), [2] [3]

By Mr. JULLIEN,
Engineer in Chief for the Permanent Way and Works of the Paris-Orleans Railway,

and Mr. CLAISE,
Director in Control of Works on New Lines and of Railway Track and Buildings at the French Ministry of Public Works.

A. — A study of the different types of reinforced concrete sleepers.

IV. — *Recent designs put forward.*

A type of reinforced concrete sleeper recently brought out by Mr. Prot, Engineer of the Bridges and Roads Department, appears to be based upon new factors and deserves to be mentioned.

This sleeper which belongs to the prismatic type would tend not only to take the place purely and simply of the wood sleeper but also to make unnecessary the use of the top part of the ballast, about 0.15 m. (6 inches) deep, known usually as the packing layer. The bearing surface of this sleeper on the lower layer of ballast is in fact equal to if not superior to that obtained with the packing layer in conjunction with a wood sleeper or of a sleeper having the same bearing surface. The sleeper is hollowed out longitudinally and this has made it possible to provide a very attractive fastening which appears well adapted to reinforced concrete.

VII. — *Methods of calculation.*

Although no method of calculation has been reported in the replies to our questionnaire, we think we ought to recall to mind the article published by Mr. de Veali in the February 1929 *Bulletin of the International Railway Congress Association.*

We must also call attention to a paper by Mr. Prot [4], the inventor of the sleeper mentioned above, as he has introduced, with just reason it would seem, into the calculation of reinforced concrete sleepers the question of the permanent settlement of the ground, whereas up to now only the effects due to elastic deflection have been taken into account.

This method would take into account the difficulties experienced with most of the prismatic sleepers actually under test.

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(1) See *Bulletin of the International Railway Congress Association*, October 1929 number, pp. 1959 and 2009.

(2) This question runs as follows : « The use of concrete and reinforced concrete on railways.

A. — Investigation into the respective merits of the different designs of concrete sleeper;

B. — Concrete and reinforced concrete buildings. »

(3) Translated from the French.

(4) *Editorial note.* — This sleeper will be described in a next number the *Bulletin of the International Railway Congress Association.*

CURRENT PRACTICE.

621. 134. 3 (.42)

Caprotti valve gear applied to London and North Eastern Railway engines.

Figs. 1 to 3, pp. 1649 to 1651.

A 4-6-0 engine of the B. 3 type, No. 6168, has been re-built and fitted with new cylinders and the Beardmore Caprotti valve gear. Figures 2 and 3 show the general arrangement of the engine as fitted with the Beardmore Caprotti gear, cylinders and smokebox.

The engine is fitted with four cylinders disposed two between the frames and two outside the frames, the inside cylinders driving the leading coupled wheels and the outside cylinders the intermediate wheels. The left hand inside is in opposite phase with the left hand outside, and likewise the right hand inside is in opposite phase to the right hand outside, and the two cranks on the crank axle are at right angles to each other as are the driving crank pins on the intermediate wheels. The valve gear is driven by gearing arranged on the centre of the intermediate coupled axle. The cardan shaft from this gear box extends forward to the transmission gear placed under the smokobox and between the cam gear boxes for driving the inlet and exhaust valves which are located one on each side of the engine above the cylinders. The cardan shaft takes a bearing in a bracket pivotted to the engine motion plate, and on this shaft behind the bearing a hook joint is arranged to take care of the movement of the cardan shaft due to the rise and fall of the engine on the axleboxes to which the driving gear is arranged.

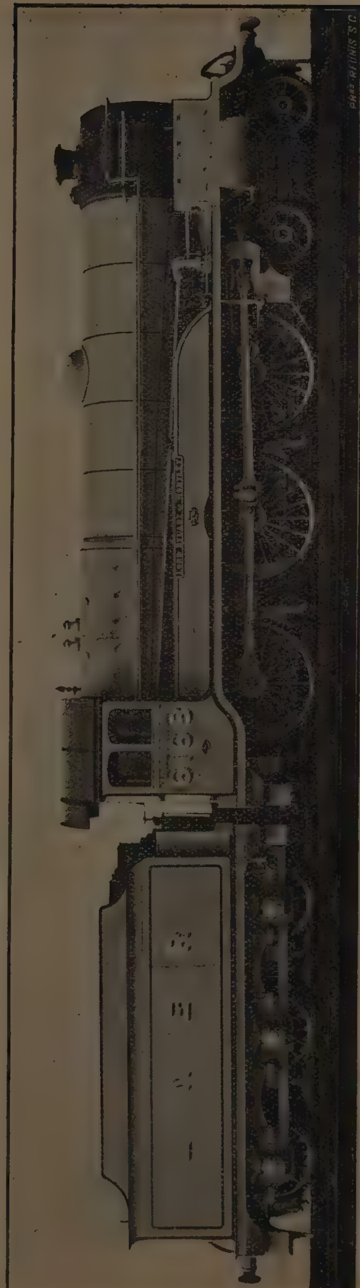

Fig. 1.

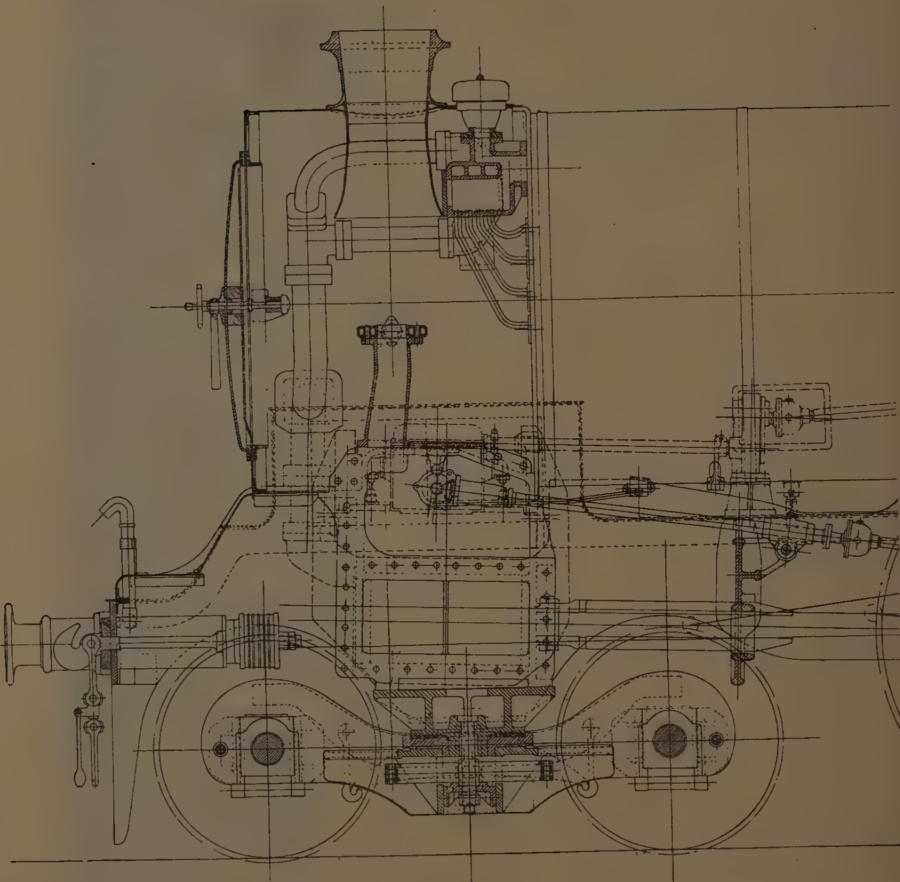

Fig. 2.

For the closing of the steam inlet and exhaust valves spring control is employed. The reversing gear placed in the right hand side of the cab consists of a wheel which does not quite make a complete turn to reverse the engine from full forward to full back gear. This wheel is attached to a shaft which rotates a tube passing down the right hand side of the engine terminating in a gear box secured to the engine platform behind the cylinders. From this gear box one shaft connects with the reversing mechanism of the valves in the valve cam box above the right hand cylinders. An arm secured on the shaft

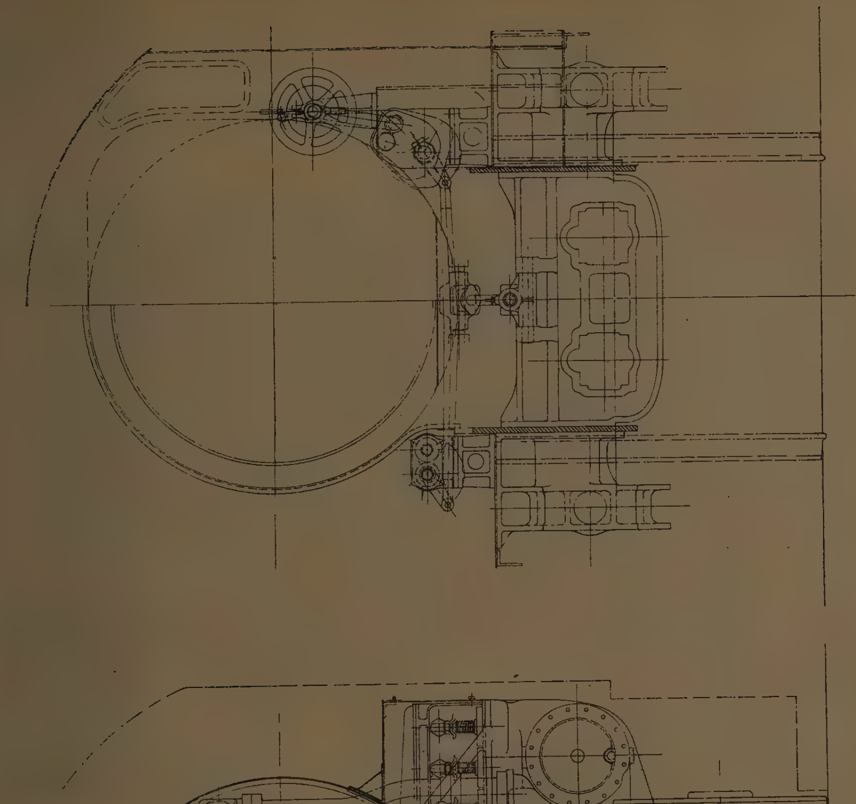

Fig. 3.

in front of the gear box is coupled up by means of rod passing under the boiler to another arm on a second gear box secured to the platform behind the left hand cylinders. This gear box in turn is provided with a shaft which operates the cam gearing in the cam box over the left hand cylinders.

The whole of the valve gearing operates in oil, the gear box on the driving axle is filled to a working level with superheater cylinder oil as required, the housing round the transmission gear between the cylinder cam boxes being kept supplied with the same grade of oil by means of an oil box fitted to the inside of the right hand frame, the outlet from this box to the pipe which communicates with the transmission gear box being kept covered with oil by the driver as required. The cam boxes over the cylinders are provided with sight glasses on the outside and these boxes are filled with oil up to the required height before the lids are put on in the shops, and the only loss of oil that takes place from these boxes is that which escapes from the dash pot tappets, which open the inlet and exhaust valves; the replenishment of oil in these cam cases need only be made at long intervals. To prevent blow through, when the engine regulator is opened, the springs to control the closing of the steam inlet valves are only made sufficiently strong to ensure the valves closing after the engine has been drifting. The strength of the spring has been made so that when drifting at approximately 5 miles per hour, the return stroke of the tappet, to open the valve, commences when the valve is still open approximately 5/16 inch. This means that the engine, when drifting, runs very freely.

Engine No. 6168 is now employed in working express passenger trains, and is giving good results, but detailed tests have not yet been made as to the saving in coal and water that will be effected.

Figure 1 shows the broadside view of engine No. 6168; a second engine, No. 6166, is in the shops at Gorton, being fitted in a similar manner to No. 6168, and will be completed shortly.

ANALYTICAL TABLE OF ARTICLES

ARRANGED ACCORDING TO THE DECIMAL CLASSIFICATION

(1930)

62. Engineering.

621. Mechanical engineering.

624. Bridges and roofs.

625. Railway and road engineering.

669. Metallurgy and assaying.

721. Architectural construction.

ERRATA.

Bulletin, August 1929 number and reprint No. 13.

Report No. 3 (British Empire, China and Japan) on the question of the *resistance of rails against breakage and to wear* (subject II for discussion at the eleventh session of the International Railway Congress Association, by S Matsunawa, Doctor of Engineering, Chief of the Research Office of the Japanese Government Railways.

Page.	Column.	Line.	Instead of :	Read :
1164	At the foot of the page add footnote as follows : « *Note.* — Southern Railway uses 2 660 feet instead of 800 metres for the radius of curvature ».			
1173	Right	24	240 cm	240 sq. cm.
1183	Left	20	New....	*b*) New....
1183	Right	4	Railway.	Rail
1197	Left	7	gravel) and broken	gravel) or broken
1207	Left	4	a.	W_{nm}
1207	Left	7	W_{nm}.	a
1207	Right	10	27.2 cm. sec.	27.2 cm. per sec.
1208	Right	1	*Victorian*.	*b*) *Victorian*.
1210	Right	3	22.4 m. (73 ft. 6 in.) ;	24.4 m. (80 ft. 5/8 in.) ;
1210	Right	20	0.75 %......	0.75 %...... Open hearth.
1212	Right	11	(60.5 lb. per yard)	(about 60 lb. per yard)
1212	Right	12	(74.6 lb. per yard)	(about 75 lb. per yard)
1212	Right	14	(100.8 lb. per yard)	(about 100 lb. per yard)
1213	Right	14	the basic process.	the acid process.
1214	Right	28	they are riveted.	rivets are also used.
1214	Right	30	hou	you
1227	Right	26	(60.5 and 74.6 lb. per yard)	(about 60 and 75 lb. per yard)
1227	Right	29	(100.8 lb. per yard)	(about 100 lb. per yard)
1230	Left	28	1/2 square inch	1/2 inch square
1230	Right	26	(60.5 and 74.6 lb.	(about 60 and 75 lb.
1230	Right	27	(100.8 lb.	(about 100 lb.

Appendix III (A rapid method of determining endurance limit by means of measuring electrical resistance).

1253	Right	7	$\sigma = \frac{32}{u}$	$\sigma - \frac{32}{\pi}$ ....
1261	Right	23	O	Θ
1265	Right	1	No. 2 Pai.	No. 2Pai.
1274	Left	41	21 kgr.	21 kgr. per
1274	Right	48	O	Θ

MONTHLY BIBLIOGRAPHY OF RAILWAYS [1]

PUBLISHED UNDER THE SUPERVISION OF

P. GHILAIN,

General secretary of the Permanent Commission of the International Railway Congress Association.

(JANUARY 1930)

[016 .385 (02]

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In French.

1929 621 .4

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Réglage et essais des moteurs à explosion.

Paris, Dunod, 92, rue Bonaparte. 1 volume (16 × cm.), 308 pages et 158 figures. (Prix : 64 fr.)

1929 721 .9

ARCOTTE (Edmond).

Règles de calcul d'exécution et d'essais.

Paris, Garnier frères. 328 pages avec figures. (Prix : francs.)

1929 621. (02

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Guide de l'ajusteur.

Paris, Ch. Béranger, 15, rue des Saints-Pères, Liége, rue des Dominicains. (155 × 240) 318 pages avec figures.

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RAUSEWETTER (Karl), Ingenieur.

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Berlin, Wilhelm Ernst & Sohn. 103 Seiten (12 × 19 cm.) t 39 Abbildungen. (Preis : 4.80 Rm.)

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Berlin, Guido Hackebeil A.-G. 38 Seiten und 23 Abbilngen.

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Der neuzeitliche Waggonbau von der Vorberechnung bis zur Inbetriebnahme.

Berlin, Laubsch & Everth. 630 Seiten mit 352 Bildern und Tafeln. (Preis : 25 Rm.)

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[1] The numbers placed over the title of each book are those of the decimal classification proposed by the Railway Congress conjointly n the Office Bibliographique International, of Brussels. See « Bibliographical Decimal Classification as applied to Railway Science », by WEISSENBRUCH in the number for November, 1897, of the *Bulletin of the International Railway Congress*, p. 1509).

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[016 .385. (05]

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1929 656 .1 & 656 2

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La collaboration du rail et de la route au Congrès d'Amsterdam. (1 400 mots.)

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1929 621 .33 (.44)

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1929 62 (01)

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LEGENS (L.). — **Calcul de l'arc doublement encastré.** (1 600 mots & fig.)

1929 669

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1929 62. (01)

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1929 62. (01)

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1929 624 .63 (.73)

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Le **pont métallique en arc de 504 mètres d'ouverture sur le Kill van Kull, près de New-York.** (800 mots & fig.)

1929 621 .335. (82+83)
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1929 621 .132 .8 & 621 .43
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Résultats obtenus au Canada et en République Argentine avec une locomotive Diesel-électrique. (900 mots & fig.)

1929 625 .212
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Essieu avec paliers à rouleaux intérieurs. (2 200 mots & fig.)

1929 621 .133 .4
Les chemins de fer et les tramways, novembre, p. 223.
Le rabattement de la fumée des locomotives. (900 mots.)

1929 621 .131 .1
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1929 625 .162
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Edgewater lubricated friction draft gear. (1 200 words & fig.)

1929 **385 .11 (.73)**
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1929 **625 .139 (.73), 625 .18 (.73) & 625 .27 (.73)**
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1929 **621 .132 .3 (.73)**
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Great Northern buys six **4-8-4 type passenger locomotives.** (700 words & 1 table.)

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1929 **625 .143 .3 (.73)**
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1929 **621 .392 (.42)**
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1929 **621 .132 .8 (.43) & 621 .133 .1 (.43)**
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SPILLER (J. W.). — **Steel sleepers** on colonial railways. (8 000 words, 3 tables & fig.)

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New **20-ton all-steel hopper ore wagons,** London Midland & Scottish Railway. (700 words & fig.)

1929 **656 .255**
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Improved methods in the **operation of single tracks.** — VIII. (2 200 words.)

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Burma Railways. — **The metre-gauge system.** (5 000 words & fig.)

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1929 385 .62
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1929 625 .4 (0
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1929 621 .138 .5
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1929 656 .254
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1929 656
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1929 656 .222 .1 (.73)
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VUILLET (G.). — **American locomotive performance.** (3 100 words & fig.)

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Résultats obtenus en 1928 sur le réseau des chemins de fer de l'Etat en France. (300 mots, 10 tables & fig.)

1930 385. (09 (.59)
Revue générale des chemins de fer, janvier, p. 43.
Chemins de fer de l'Indochine française. (6 400 mots & fig.)

1930 621 .8 (.43)
Revue générale des chemins de fer, janvier, p. 56.
Développement des moyens de manutention. (800 mots & fig.)

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1929 385. (01 (.6)
Rev. politique et parlementaire, n° 421, 10 déc., p. 438.
RAYNAUD (R.). — **L'état des études du Transsaharien.** (3 900 mots.)

1929 38
Rev. politique et parlementaire, n° 421, 10 déc., p. 478.
COLSON (C.). — **Revue des questions de transport.** (300 mots.)

Revue universelle des mines, de la métallurgie, des travaux publics, des sciences et des arts appliqués à l'industrie. (Liége.)

1929 721 .1
Revue universelle des mines, n° 12, 15 décembre, p. 353.
CAMPUS (F.). — **Les moyens de parer aux effets des affaissements des terrains sur les constructions** (suite et fin). (10 000 mots & fig.)

1930 621 .112 (.73)
Revue universelle des mines, n° 1, 1er janvier, p. 14.
DILLON (E.). — **Expérience de l'exploitation avec vapeur à haute pression à Boston.** (5 700 mots & fig.)

Revue universelle des transports et des communications. (Paris.)

1929 385. (01 (.6)
Rev. univ. des transp. et des communic., déc., p. 234.
CAPITAN (H.). — **Le Transsaharien.** — Essai de contribution à son étude (suite et fin). (2 300 mots.)

1929 385 .113 (.494)
Rev. univ. des transp. et des communic., déc., p. 237.
BOIVIN (A.). — **L'exploitation des Chemins de fer fédéraux suisses en 1928.** (1 800 mots.)

1929 625 .62
Rev. univ. des transp. et des communic., déc., p. 242.
Le lavages des voitures de tramways. (900 mots & fig.)

In German.

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1929 385. (09 (.81)
Archiv für Eisenbahnwesen, Heft 3, Mai-Juni, S. 535.
STINNER. — **Brasilianische Centralbahn.** (10 000 Wörter.)

1929 385 .1 (.494) & 656 .23 (.494)
Archiv für Eisenbahnwesen, Heft 3, Mai-Juni, S. 565.
MIESCHER (O.). — **Die finanziellen Ursachen der hohen schweizerischen Eisenbahntarife.** (7 000 Wörter.)

1929 625 .111 (.43)
Archiv für Eisenbahnwesen, Heft 3, Mai-Juni, S. 583.
KELLER (E.). — **Die verkehrsgeographischen Grundlagen der deutschen Eisenbahnumwege** mit besonderer Berücksichtigung von Nord- und Mitteldeutschland. (Schluss.) (18 000 Wörter & 1 Karte.)

1929 385. (09 (.56)
Archiv für Eisenbahnwesen, Heft 3, Mai-Juni, S. 631.
DIECKMANN. — **Die Eisenbahnen im Irak.** (9 000 Wörter & 1 Karte.)

1929 385. (09 (.51)
Archiv für Eisenbahnwesen, Heft 3, Mai-Juni, S. 657.
CREMER (M.). — **Die Ostchinesische Bahn.** — Der Teil der Transsibirischen Bahn von Mandschurei bis Kuantschentzy. (7 500 Wörter.)

1929 385 .113 (.43)
Archiv für Eisenbahnwesen, Heft 3, Mai-Juni, S. 677.
Archiv für Eisenbahnwesen, Heft 4, Juli-August, S. 855.
Die Deutsche Reichsbahn im Geschäftsjahr 1927. (12 700 Wörter.)

1929 385 .113 (.45)
Archiv für Eisenbahnwesen, Heft 3, Mai-Juni, S. 722.
Die italienischen Staatsbahnen im Rechnungsjahr 1926-1927. (6 600 Wörter.)

1929 385 .113 (.489)
Archiv für Eisenbahnwesen, Heft 3, Mai-Juni, S. 740.
Die Eisenbahnen in Dänemark in den Betriebsjahren 1926-1927 und 1927-1928. (3 000 Wörter.)

1929 385 .5 (.47)
Archiv für Eisenbahnwesen, Heft 4, Juli-August, S. 855.
WEHDE-TEXTOR. — **Das Arbeitsrecht der russischen Eisenbahnbediensteten** und Arbeiter. (8 000 Wörter.)

1929 385 .517 (.43)
Archiv für Eisenbahnwesen, Heft 4, Juli-August, S. 971.
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KUHATSCHECK (O.), — **Die Kranken- und Arbeiterpensionskassen**, die Angestellten-, Unfall- und Arbeitslosenversicherung bei der Deutschen Reichsbahn im Jahr 1928. (24 700 Wörter.)

1929 385 .113 (.47)
Archiv für Eisenbahnwesen, Heft 4, Juli-Aug., S. 1001.
ROESNER (E.). — **Die Staatsbahnen von Litauen** im Rechnungsjahr 1927. (2 000 Wörter.)

1929 385 .113 (.56)
Archiv für Eisenbahnwesen, Heft 4, Juli-Aug., S. 1010.
Die Smyrna-Cassaba-Eisenbahn. (2 800 Wörter.)

1929 385. (09 (.496 + .56)
Archiv für Eisenbahnwesen, Heft 5, Sept.-Okt., S. 1151.
DIECKMANN. — **Die türkischen Staatseisenbahnen.** (9 000 Wörter & 1 Karte.)

1929 385. (09 (.51)
Archiv für Eisenbahnwesen, Heft 5, Sept.-Okt., S. 1195.
Entwicklung des chinesischen Eisenbahnwesens seit 1928. (1 500 Wörter.)

1929 385 .113 (.47)
Archiv für Eisenbahnwesen, Heft 5, Sept.-Okt., S. 1231.
WEHDE-TEXTOR. — **Die russischen Eisenbahnen** im Wirtschaftsjahr 1926-1927.

1929 385. (09 (.47)
Archiv für Eisenbahnwesen, Heft 5, Sept.-Okt., S. 1245.
Die **Entwicklung der lettischen Eisenbahnen.** (6 300 Wörter.)

1929 313 .385 (.485)
Archiv für Eisenbahnwesen, Heft 5, Sept.-Okt., S. 1267.
Das schwedische Eisenbahnnetz 1926 und 1927. (4 800 Wörter.)

1929 385 .113 (.481)
Archiv für Eisenbahnwesen, Heft 5, Sept.-Okt., S. 1281.
Die Eisenbahnen in Norwegen in den Jahren 1926-1927 und 1927-1928. (2 200 Wörter.)

1929 385 .113 (.439)
Archiv für Eisenbahnwesen, Heft 5, Sept.-Okt., S. 1291.
RAJZ (K.). — **Die königlich-ungarischen Staatsbahnen** im Betriebsjahr 1926-1927.

1929 385 .113 (.498)
Archiv für Eisenbahnwesen, Heft 5, Sept.-Okt., S. 1304.
Die rumänischen Staatsbahnen im Jahr 1926. (2 500 Wörter.)

1929 385 .113 (.44)
Archiv für Eisenbahnwesen, Heft 5, Sept.-Okt., S. 1314.
Die Betriebsergebnisse der fünf grossen französischen Eisenbahngesellschaften im Jahre 1927.

1929 347 .234
Archiv für Eisenbahnwesen, Heft 6, Nov.-Dez., S. 1405.
DURNIOK (E.). — **Die Entstehung des heutigen Enteignungsrechts** aus den Besonderheiten des Eisenbahnbaus. (Schluss folgt.) (12 000 Wörter.)

1929 385. (09 (.61)
Archiv für Eisenbahnwesen, Heft 6, Nov.-Dez., S. 1435.
DIECKMANN. — **Die Eisenbahnen** und die **Nilschifffahrt im Sudan.** (5 800 Wörter, 1 Karte & Abb.)

1929 385 .113 (.494)
Archiv für Eisenbahnwesen, Heft 6, Nov.-Dez., S. 1486
Die Schweizerischen Bundesbahnen im Jahr 1928.

1929 385 .113 (.42)
Archiv für Eisenbahnwesen, Heft 6, Nov.-Dez., S. 1492
ROESNER. (E.). — **Die lettischen Eisenbahnen** in den Rechnungsjahren 1926-1927 und 1927-1928.

1929 385 .113 (.495)
Archiv für Eisenbahnwesen, Heft 6, Nov.-Dez., S. 1509
Die Griechische Staatsbahn in den Jahren 1926-1927 und 1927-1928. (3 000 Wörter.)

1929 385 .113 (.460)
Archiv für Eisenbahnwesen, Heft 6, Nov.-Dez., S. 1517
Die Madrid-Zaragoza- und Alicante-Eisenbahn im Jahr 1927. (5 600 Wörter.)

1929 385 .113 (.73)
Archiv für Eisenbahnwesen, Heft 6, Nov.-Dez., S. 1534
Die Eisenbahnen der Vereinigten Staaten von Amerika in den Jahren 1926 und 1927. (6 000 Wörter.)

1929 313 .385 (.56
Archiv für Eisenbahnwesen, Heft 6, Nov.-Dez., S. 1558
Die Eisenbahnen im Irak. (2 000 Wörter.)

Elektrische Bahnen. (Berlin.)

1929 621 .335 (.45
Elektrische Bahnen, Heft 1, Januar, S. 1.
Elektrische Bahnen, Heft 2, Februar, S. 37.
SACHS (Dr. K.). — **Neuere Drehstromlokomotive der Italienischen Staatsbahnen.** (7 200 Wörter & Abb.

1929 621 .335 (.494
Elektrische Bahnen, Heft 1, Januar, S. 19.
CHOISY (E. G.). — **Les automotrices de 1 100 c des chemins de fer fédéraux suisses.** (4 500 Wörte & Abb.)

1929 625 .223 (.43
Elektrische Bahnen, Heft 2, Februar, S. 33.
WAGNER (G.). — **Die elektrische Beleuchtung de neuen Berliner Stadtbahnwagen mit versenkten Decken**leuchten. (1 600 Wörter & Abb.)

1929 625 .23
Elektrische Bahnen, Heft 3, März, S. 65.
STEINER (F.). — **Über das Vorheizen der Züg** (4 500 Wörter & Abb.)

1929 621 .33 (.43)
lektrische Bahnen, Heft 4, April, S. 97.

MUHL (H.). — **Das vierte Betriebsjahr im elektrierten Streckengebiet Bayerns der Deutschen Reichsahn Gesellschaft.** (6 600 Wörter & Abb.)

1929 621 .33 (.73)
ektrische Bahnen, Heft 4, April, S. 113.

ZEHNDER-SPÖRRY (R.). — Einige Angaben über **e Elektrisierung nordamerikanischer Bahnen.** (4 000 örter & Abb.)

1929 621 .332 (.494)
ektrische Bahnen, Heft 4, April, S. 121.

SCHULER (H. W.). — **Schienenleitung und Erdung i den Schweizerischen Bundesbahnen.** (Fortsetzung lgt.) (2 800 Wörter & Abb.)

1929 621 .332 (.494)
ektrische Bahnen, Heft 5, Mai, S. 145.

SCHULER (H. W.). — **Schienenleitung und Erdung i den Schweizerischen Bundesbahnen.** (Schluss.) 900 Wörter & Abb.)

1929 625 .234
ektrische Bahnen, Heft 6, Juni, S. 166.

RAUCH (A.). — **Elektrische Zugheizung.** — Wagen den Übergangsverkehr, die sowohl mit 1 000 Volt echselstrom wie mit 1 500 Volt Gleichstrom geheizt rden. (Schluss folgt.) (4 300 Wörter & Abb.)

1929 621 .332 (.485)
ektrische Bahnen, Heft 12, Dezember, S. 361.

ÖFVERHOLM (I.). — **Die elektrischen Energieertragungsanlagen** der Schwedischen Staatseisenhnen. (4 800 Wörter, 2 Karten & Abb.)

1929 621 .33 (.43)
ektrische Bahnen, Heft 12, Dezember, S. 369.

LEICHMANN. — Eine wichtige **Urkunde für den ktrischen Zugbetrieb auf den deutschen Haupteisenanen.** (2 100 Wörter & Abb.)

1929 621 .33 (.43)
ktrische Bahnen, Heft 12, Dezember, S. 375.

RAMPACHER (F.) & WEBER (P.). — **Der Entwickgsgang der Leitungskupplungen** für elektrische hnen. (2 300 Wörter & Abb.)

Elektrotechnische Zeitschrift. (Berlin.)

929 621 .331 (.47)
ktrotechnische Zeitschrift, Heft 49, 5. Dez., S. 1757.

LFTAN (Alf.). — **Das Kraftwerk Imatra.** (1 800 rter & Abb.)

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929 656 .215
ktrotechnische Zeitschrift, Heft 50, 12. Dez., S. 1802.

UNGETHAL (W.). — **Scheinwerferbeleuchtung von isanlagen.** (1 100 Wörter & Abb.)

1929 625 .4 (.44)
Elektrotechnische Zeitschrift, Heft 50, 12. Dez., S. 1813.

Die neuere **Entwicklung der Pariser Untergrundbahnen.** (1 300 Wörter & Abb.)

1929 621 .335 (.494)
Elektrotechnische Zeitschrift, Heft 51, 19. Dez., S. 1841.

MÜLLER (A. E.). — **Die Triebwagen der Bern Neuenburg-Bahn.** (1 300 Wörter & Abb.)

1929 621 .33 (.43)
Elektrotechnische Zeitschrift, Heft 51, 19. Dez., S. 1854.

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1929 621 .39 (.436)
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Fortschritte der **Elektrisierung der Österreichischen Bundesbahnen.** (400 Wörter.)

1930 725 .1 (.43)
Elektrotechnische Zeitschrift, Heft 1, 2. Januar, S. 13.
Elektrotechnische Zeitschrift, Heft 2, 9. Januar, S. 50.

STÜBLER (H.). — **Die Stromversorgungsanlage und die elektrischen Einrichtungen des Reichspostzentralamts.** (8 000 Wörter & Abb.)

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1929 621 .83
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KLEIN (R.). — Einiges aus der **Praxis des Getriebebaues.** (3 200 Wörter & Abb.)

1929 625 .25
Glasers Annalen, Nr 1259, 1. Dez., S. 171.

ERDOS (E.). — **Veränderungen der Achsdrücke bei Lokomotiven und Wagen** unter dem Einflusse der Bremskräfte. (2 100 Wörter, Tafel & Abb.)

1929 621 .132.8
Glasers Annalen, Nr 1259, 1. Dezember, S. 175.

WERNEKKE. — **Eine Lokomotive mit Kettenantrieb.** (900 Wörter & Abb.)

1929 625 .251
Glasers Annalen, Nr 1260, 15. Dezember, S. 187.

ERDOS (E.). — **Veränderungen der Achsdrücke bei Lokomotiven und Wagen** unter dem Einflusse der Bremskräfte. (Schluss.) (3 800 Wörter & Abb.)

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1929 625 .1 (02 (.73)
Bulletin American Railway Eng. Ass^on, October, p. 337.

Report of special committee on standardization. (3 700 words & fig.)

1929 725 .33 (.73)
Bulletin American Railway Eng. Ass[on], October, p. 409.
Report of committee XIII. — **Water service and sanitation.** (32 000 words & fig.)

1929 625 .162 (.73
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Report of committee IX. — **Grade crossings.** (8 000 words & fig.)

1929 347 .75 (.73)
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Report of committee XX. — **Uniform general contract forms.** (21 000 words & fig.)

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1930 625 .7 (.42) & 656 .1 (.42)
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CLEMENTS (R. G. H.). — **Road engineering in relation to road transport.** (10 700 words & 4 tables.)

1930 385 .15 (.42)
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MILLER (H. T. G.). — **Should british railways be nationalised?** (4 600 words.)

1930 385. (07.2
Journal of the Institute of Transp., No. 3, Jan., p. 152.
PRESCOTT (W. G.). — **Transportation from a chemist's point of view.** (2 600 words.)

Locomotive Railway Carriage & Wagon Review. (London).

1929 621 .132.3 (.492)
Loc. Ry. Car. & Wagon Rev., No. 448, Dec. 14, p. 375.
New **express engines,** Netherlands Railways. (900 words & fig.)

1929 621 .132.5 (.44)
Loc. Ry. Car. & Wagon Rev., No. 448, Dec. 14, p. 376.
Locomotive development on the Eastern Railway of France. (2 000 words & fig.)

1929 621 .131
Loc. Ry. Car. & Wagon Rev., No. 448, Dec. 14, p. 390.
PHILLIPSON (E. A.). — **Steam locomotive design : data and formulae** (to be continued). (2 600 words.)

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1929 388 (.431)
Modern Transport, No. 562, 21 December, p. 3.
Passenger transport services in Berlin. No. 1. — Development of the Untergrundbahn system. (5 400 words & fig.)

1929 656 .21
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JENKIN JONES (C. M.). — **Layout and equipmen of docks.** — Relations between railways and port (4 800 words & fig.)

1929 385. (09 (.5
Modern Transport, No. 562, 21 December, p. 9.
BURTT (Ph.). — **The railway position in the Eas** (1 400 words.)

1929 656 .25
Modern Transport, No. 562, 21 December, p. 11.
PETER (B. H.). — **Developments in railway signalling.** (2 900 words.)

1929 621 .132.8 (.42) & 621 .134.3 (.42
Modern Transport, No. 562, 21 December, p. 15.
New British-built « Baltic » type **high pressure locomotive with water-tube boiler.** (1 400 words & fig.)

1929 651 (.42
Modern Transport, No. 562, 21 December, p. 20.
Advertising railway services. (2 000 words.)

1929 388 (.43
Modern Transport, No. 563, 28 December, p. 3.
Passenger transport services in Berlin. No. 2. — Power, rolling-stock and stations. (2 200 words & fig.

1929 621 .132.3 (.42
Modern Transport, No. 563, 28 December, p. 9.
New **high-pressure three-cylinder compound locomotive** for London Midland and Scottish Railway. (90 words & fig.)

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1929 656 .255 (.73
Railway Age, No. 23, 7 December, p. 1322.
Normal and reverse direction signals solve operati problem for Denver & Rio Grande Western on mounta grade. (1 300 words & fig.)

1929 621 .132.3 (.73) & 621 .132.5 (.7
Railway Age, No. 23, 7 December, p. 1325.
Rock Island buys **4-8-4 type locomotives.** (1 000 wor & fig.)

1929 621 .133.7 (.7
Railway Age, No. 23, 7 December, p. 1329.
KOYL (C. H.). — **Pitting reduced by feedwat heater.** (1 500 words & fig.)

1929 621 .134.5 (.7
Railway Age, No. 23, 7 December, p. 1331.
Illinois Central runs **lubrication test.** (1 400 wo & fig.)

1929 657 (.7
Railway Age, No. 23, 7 December, p. 1334.
JOHNSTON (C. E.). — **How the Kansas C Southern allots expenditures.** (3 000 words & fig.

1929 385 .3 (08 (.73)
Railway Age, No. 23, 7 December, p. 1337.
Interstate Commerce Commission annual report. (6 200 words & fig.)

1929 625 .175 (.73)
Railway Age, No. 23, 7 December, p. 1341.
A Fairmont **inspection car.** (600 words & fig.)

1929 624 .63 (.73)
Railway Age, No. 23, 7 December, p. 1342.
Steel trusses support forms for concrete arch bridge. (600 words & fig.)

1929 621 .132.7 (.73)
Railway Age, No. 24, 14 December, p. 1367.
Illinois Central buys eight-wheel switchers. (600 words & fig.)

1929 657 (.73)
Railway Age, No. 24, 14 December, p. 1369.
HOWSON (E. T.). — **Railway budgets an aid to orderly spending.** (6 200 words & fig.)

1929 657 (.73)
Railway Age, No. 24, 14 December, p. 1374.
Arguments in accounting cases. (4 300 words.)

1929 625 .232 (.73)
Railway Age, No. 24, 14 December, p. 1377.
An unusual **club car** for the Lehigh Valley. (500 words & fig.)

1929 621 .118 (.73)
Railway Age, No. 24, 14 December, p. 1385.
Annual report of Bureau of locomotive inspection. (..00 words & fig.)

1929 625 .258 (.73)
Railway Age, No. 24, 14 December, p. 1387.
Big Four installs retarders at Sharonville yard. (2 100 words & fig.)

1929 621 .139 (.73), 625 .18 (.73) & 625 .27 (.73)
Railway Age, No. 25, 21 December, p. 1415.
Union Pacific opens system reclamation plant. (2 600 words & fig.)

1929 621 .132.5 (.73)
Railway Age, No. 25, 21 December, p. 1419.
ARMSTRONG (G. W.). — **Locomotive auxiliary power mediums.** (2 200 words, 2 tables & fig.)

1929 625 .13 (.73)
Railway Age, No. 25, 21 December, p. 1423.
..OPRIS (R. F.). — **Steam operation no obstacle to .. of Moffat tunnel.** (3 800 words & fig.)

1929 659 (.42)
Railway Age, No. 25, 21 December, p. 1428.
..ANDRIDGE (C.). — **Co-operative advertising in Britain.** (300 words & fig.)

1929 621 .335 (.73)
Railway Age, No. 25, 21 December, p. 1430.
St. Louis combination **electric switcher tested.** (1 700 words & fig.)

1929 385 .3 (.73)
Railway Age, No. 25, 21 December, p. 1435.
LEWIS (E. I.). — **Functions of the Interstate Commerce Commission.** (4 000 words.)

1929 656 .26 (.73)
Railway Age, No. 25, 21 December, p. 1441.
KEELEY (J.). — **Pullman service result** of twenty-two years' development. (1 900 words.)

Railway Gazette. (London.)

1929 625 .232 (.942)
Railway Gazette, No. 25, 20 December, p. 961.
New **rail motor car trailer, South Australian Railways.** (600 words & fig.)

1929 621 .33 (.54)
Railway Gazette, No. 25, 20 December, p. 962.
Great Indian Peninsula Railway electrification. (700 words & fig.)

1929 621 .9 (.42)
Railway Gazette, No. 25, 20 December, p. 964.
A new **boring, facing and radiusing machine.** (500 words & fig.)

1929 656 .1 (.41)
Railway Gazette, No. 25, 20 December, p. 967.
Rail and road services in Ireland. (1 400 words & fig.)

1929 621 .132.8 (.42) & 621 .134.3 (.42)
Railway Gazette, No. 25, 20 December, p. 973.
High-pressure compound locomotive, London and North Eastern Railway. (1 600 words & fig.)

1929 625 .1 (.42)
Railway Gazette, No. 25, 20 December, p. 976.
The Wimbledon to Sutton line, Southern Railway. (700 words & fig.)

1929 625 .246 (.43)
Railway Gazette, No. 25, 20 December, p. 978.
20-ton goods brake van with ferro-concrete body. (200 words & fig.)

1929 656 .211.7 (73)
Railway Gazette, No. 26, 27 December, p. 997.
The Havana-New Orleans ferry service. (500 words & fig.)

1929 621 .335 (.54) & 621 .338 (.54)
Railway Gazette, No. 26, 27 December, p. 1001.
Special trains for the Poona Mail service, Great Indian Peninsula Railway. (800 words & fig.)

1929 656 .255
Railway Gazette, No. 26, 27 December, p. 1002.
The operation of single lines of railway. — XXIV. (1 800 words & fig.)

1929 625 .1 (.44 + .45)
Railway Gazette, No. 26, 27 December, p. 1004.
The Cuneo-Ventimiglia Railway. (1 000 words & fig.)

1930 656 .21 (.42) & 656 .225 (.42)
Railway Gazette, No. 1, 3 January, p. 11.
PAYNE (H. W.). — **Tranship traffic.** (1 100 words & fig.)

1930 656 .255
Railway Gazette, No. 1, 3 January, p. 16.
The operation of single lines of railway. XXV. (1 700 words & fig.)

1930 621 .132.3 (.42)
Railway Gazette, No. 1, 3 January, p. 20.
The new « Royal Scot » **high-pressure locomotive,** London Midland and Scottish Railway. (500 words.)

1930 623 .176 (.54)
Railway Gazette, No. 1, 3 January, p. 20.
Gauge conversion, South Indian Railway. (900 words.)

1930 385. (09.1 (.728)
Railway Gazette, No. 1, 3 January, p. 22.
International Railways of Central America. (1 000 words & fig.)

In Spanish.

Gaceta de los Caminos de hierro. (Madrid.)

1929 625 .251
Gac. de los Cam. de hierro, 1° de Dic., n° 3604, p. 397.
Las **corrientes de Foucault utilizadas para el frenage automatico.** (800 palabras.)

1929 621 .332
Gac. de los Cam. de hierro, 20 de Dic., n° 3606, p. 421.
Protección de las lineas eléctricas contra el rayo. (900 palabras.)

Ingenieria y Construcción. (Madrid.)

1929 621 .33 (.460)
Ingenieria y Construccion, Diciembre, p. 637.
GILBERT y SALINAS (A.). — **En torno al sistema de corriente má adecuado para la electrificacion de los ferrocarriles españoles** (continuara). (8 000 palabras.)

1929 385. (06.4 (.460)
Ingenieria y Construccion, Diciembre, p. 649.
Las exposiciones de Sevilla y Barcelona. (22 000 palabras & fig.)

Los Transportes. (Madrid.)

1929 625 .1 (.44 + .460
Los Transportes, n° 266, 15 Octubre, p. 292.
Vià internacional entre Irun y San Sebastián. (2 50 palabras & fig.)

1929 625 .14
Los Transportes, n° 269, 30 Noviembre, p. 340.
La conservación de las traviesas y de los postes d los ferrocarriles. (1 100 palabras & fig.)

1929 625 .142.
Los transportes, n° 270, 15 Diciembre, p. 357.
La conservación de las traviesas y de los postes en lo ferrocarriles. (700 palabras & fig.)

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1930 69
Revista de Obras Publicas, 1° de Enero, p. 5.
SIERRA (L.). — **Sobre la dosificación de hormigone** (900 palabras & fig.)

1930 385. (09 (.493
Revista de Obras Publicas, 1° de Enero, p. 12.
JUANES (R.). — Los ferrocarriles belgas. (5 0 palabras & fig.)

In Italian.

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1929 621 .33 ((
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BARAVELLI (P.). — **A proposito di una determin zione delle caratteristiche fondamentali per ferrov elettriche.** (11 500 parole.)

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1929 656 .1 & 656
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VEZZANI (F.). — **Strade, autostrade e ferrov** (continuazione). (8 500 parole & 3 quadri.)

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1930 625 .2
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Il transporto di rotaie e ferri lunghi su carri co giunti. (1 000 parole & fig.)

1930 62. ((
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La resilienza. (3 600 parole & fig.)

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1929 385 .113 (.45)
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I risultati dell' esercizio ferroviario nell' anno 1928-1929. (2 300 parole.)

Rivista tecnica delle ferrovie italiane. (Roma.)

1929 621 .33 (.45)
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GRANDI (C.). — **Elettrificazione della linea Bolzano-Brennero.** (2 600 parole & fig.)

1929 625 .13 (.45)
Rivista tecnica delle ferrovie italiane, 15 nov., p. 202.
VALLECHI (U.). — **Verifiche di stabilita dei rivestimenti di galleria per le ferrovie metropolitane di Roma** (continua). (8 700 parole & fig.)

In Dutch.

De Ingenieur. (Den Haag.)

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De Ingenieur, Nr 50, 14 December, bl. 101.
FOL (J. G.) & DE VISSER (W.). — **Rubber onder rails.** (3 600 woorden, 5 tafereelen & fig.)

De Locomotief. (Amsterdam.)

1930 625 .62 (.492)
De Locomotief, Nr 51, 18 December, bl. 401.
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NIEUWENHUIS (J. G. J. C.). — **Nieuw rollend materieel** voor de Rotterdamsche elektrische tram. (700 woorden & fig.)

Spoor- en Tramwegen. (Utrecht.)

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Spoor- en Tramwegen, Nr 12, 10 December, bl. 300.
Spoor- en Tramwegen, Nr 13, 24 December, bl. 330.
Spoor- en Tramwegen, Nr 1, 7 Januari, bl. 4.
DE GRUYTER (P.). — **Het meetrijtuig der Nederlandsch-Indische staatsspoorwegen.** (6 800 woorden & fig.)

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SCHONG (C. L. M.). — **Het Wig-Wag signaalsysteem** voor onbewaakte overwegen. (900 woorden & fig.)

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MARIS (A.). — **Versterking van de brug over het Hollandsch diep.** (3 100 woorden & fig.)

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BRONKHORST (W. F. N.). — **Het ponskaartensysteem** in de administratie der Nederlandsche Spoorwegen. (1 800 woorden & fig.)

In Portuguese.

Boletim do Instituto de Engenharia. (S. Paulo.) (Brasil.)

1929 621 .33 (.81)
Boletim do Instituto de Engenharia, Novembro, p. 335.
MARINHO DE AZEVEDO (E. R.). — **A electrificação das linhas de suburbios** entre as estações de D. Pedro II e Bangii da E. F. Central do Brasil. (Continuaçao e fien.) (12 400 palavras & fig.)

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Boletim do Instituto de Engenharia, Novembro, p. 372.
de CASTRO BARBOSA (J.). — **Da organizaçao do trafego ferroviario.** (Continuaçao.) (4 300 palavras & fig.)

Revista das Estradas de Ferro. (Rio de Janeiro.)

1929 621 .132.8 & 621 .335
Revista das Estradas de ferro, 30 de Novembro, p. 522.
As automotrizes à transmissâo electrica. (1 000 palavras & fig.)

1929 621 .335 (.494)
Revista das Estradas de ferro, 15 de Dezembro, p. 539.
A nova locomotiva de Loetschberg. (1 200 palavras & fig.)

8455. — Publisher : M. Weissenbruch Co., Ltd., Printer to the King, 49, rue du Poinçon, Brussels.

OL. XII. — N° 6.

JUNE 1930.

Monthly Bulletin of the International Railway Congress Association

(English Edition)

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Independently operated doors

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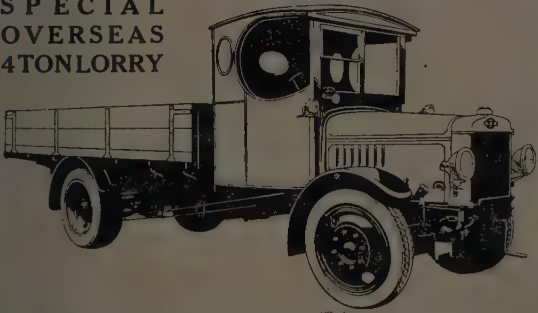

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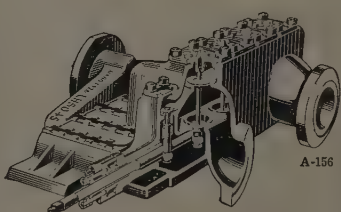

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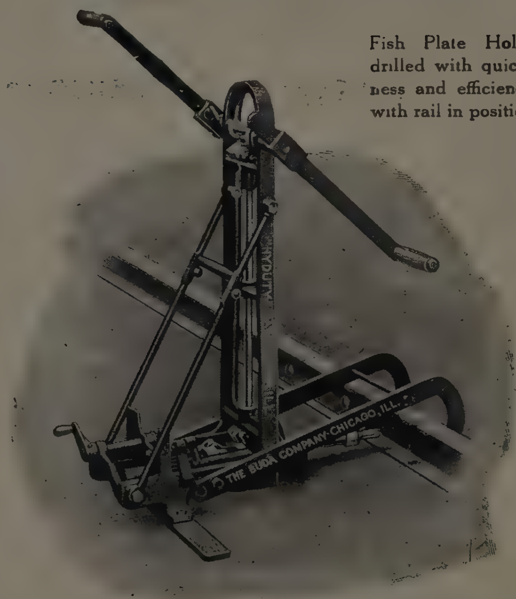

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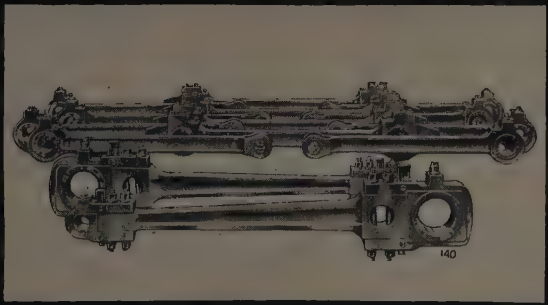

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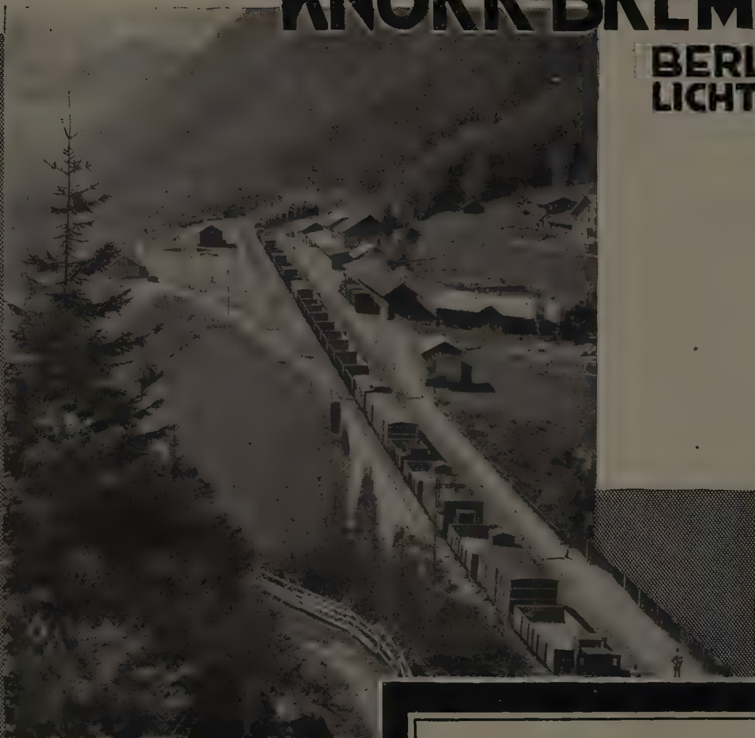

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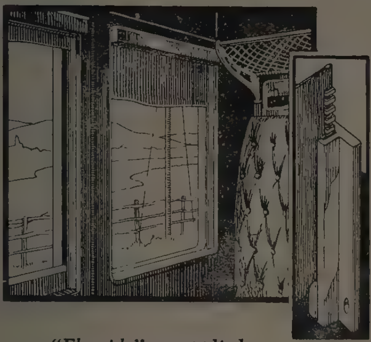

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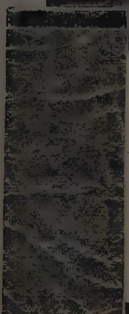

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R.A.170

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At the present time, owing to the very great increase in the running weight of both passenger and freight vehicles, and the increased speed at which trains are marshalled and freight cars are shunted, the force of impact at which wagons meet is no longer to be stated in a number of tons of the order of units up to 10 tons, but is now to be calculated in terms of 10^2.

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